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CONTENTS

PAGES

Northern end of the Taconic thrust sheet in western Vermont. By E. P. Kaiser..... 1079-1098

Sediments of Trout Lake, Wisconsin. By W. H. Twenhofel, V. E. McKelvey, H. F. Nelson, and D. E. Feray..... 1099-1142

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PAPERS IN PRESS FOR FORTHCOMING ISSUES

Contribution to the Petrography of Haleakala Volcano, Hawaii. By Gordon A. Macdonald and Howard A. Powers

Standard of the European Jurassic. By W. J. Arkell

Lower Middle Ordovician Stratigraphy of the Shenandoah Valley, Virginia. By B. N. Cooper and G. Arthur Cooper

Gneiss Dome at Shelburne Falls, Mass. By Robert Balk

Preglacial History of Bermuda. By H. B. and D. M. Moore

Structure and Metamorphism of the Bellows Falls Quadrangle, New Hampshire and Vermont. By F. C. Kruger

Geology of a Part of the Lower Conchos Valley, Chihuahua, Mexico. By R. E. King and W. S. Adkins

Igneous and Metamorphic Rocks of the Southwestern Part of the Ramona Quadrangle, San Diego County, Calif. By Richard Merriam

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NORTHERN END OF THE TACONIC THRUST SHEET IN WESTERN VERMONT

BY E. P. KAISER

CONTENTS

	Page
Abstract	1079
Introduction	1080
Geologic environment	1081
Previous work	1082
Stratigraphy	1083
General	1083
Bomoseen grit	1085
Mettawee slate	1085
Eddy Hill grit	1086
Schodack formation	1087
Wallace Ledge formation	1089
Zion Hill formation	1089
Berkshire schist and Bird Mountain grit	1089
Normanskill formation	1090
Summary of stratigraphic relations	1091
Site of deposition	1091
Structure	1092
Map structure	1092
Small-scale structures	1093
Metamorphism	1094
The Taconic thrust	1094
Review of previous work	1094
Structural evidence	1095
Stratigraphic evidence	1096
Summary of conclusions	1096
References cited	1097

ILLUSTRATIONS

Figure	Page
1. Key to published maps of the northern and central Taconic area	1080
Plate	**Facing page**
1. Geology of the northern Taconic area	1098

ABSTRACT

The north end of the Taconic Range has been studied in order to clarify the structural and stratigraphic relations. The Taconic sequence correlates with that in the Vermont slate belt and in the Saratoga and Albany districts. Keith's sequence is rejected. The Taconic slates are thrust over the limestone-dolomite-slate series of the Champlain and Vermont valleys. On a large scale the rocks lie nearly flat, but intense small-scale crumpling occurs. Because of local juxtaposition of identical black slates of different ages, and perhaps because of post-fault metamorphism, the position of the Taconic thrust is locally obscure, but its existence is demonstrated.

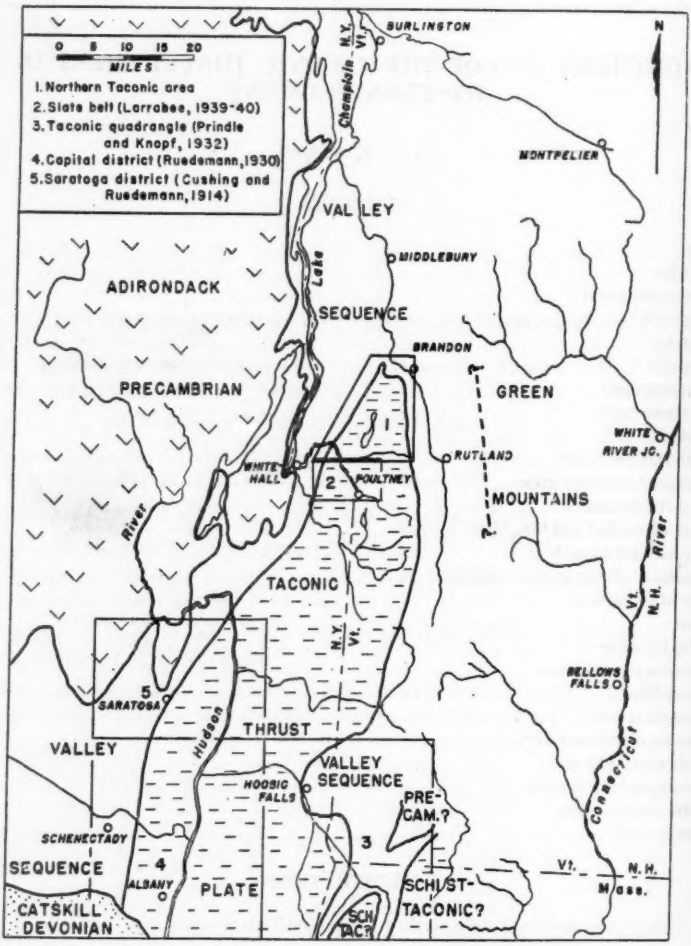

FIGURE 1.—*Key to published maps of the northern and central Taconic area*

INTRODUCTION

Vermont's eastern margin is the Connecticut River; its backbone the long north-south ridge of the Green Mountains; and its western border, north of Whitehall, N. Y., the great trough of the Champlain Valley which joins the Hudson River Valley to the south (Fig. 1). Along the western foot of the Green Mountains the narrow Vermont Valley traverses the State from the Massachusetts line to Brandon, where it joins the Champlain Valley. Between the Vermont Valley and the Champlain-Hudson Valley to the west, the Taconic Range, a physiographic unit distinct from

and west of the Green Mountains, extends from Brandon southward into Massachusetts and New York.

Geologically also the Taconic Range is distinct, for it is believed that its great body of slaty rock, flanked on three sides by limestones and dolomites of the Vermont and Champlain-Hudson valleys, was pushed many miles westward from its original location and came to rest on top of the limestones and dolomites, although it is in part older than these rocks.

Part of this paper investigates this theory, which is still not unanimously accepted. The structural relations of the Taconic rocks constitute a major problem which could not be solved until the stratigraphic sequence was determined. The problem of the sequence formed a major part of the once-famous Taconic Question and was resurrected by the perplexing incompatibility of Keith's work with earlier work of Dale and Ruedemann.

The writer studied the northern end of the Taconic Range, a roughly triangular area (Fig. 1) bounded on the south by the Castleton Valley which runs from Rutland westward through the range to Whitehall, N. Y. The northern termination of the area, near Brandon, is about 16 miles north of the Castleton Valley. Field work was done during the summers of 1938, 1939, and 1940.

It is a pleasure to acknowledge the fruitful exchange of ideas during field work and discussion with W. M. Cady, and the helpful criticism and inspiration of Prof. H. W. Fairbairn and Prof. G. M. Kay.

GEOLOGIC ENVIRONMENT

The westernmost part of the Green Mountain Range consists of crystalline schists and gneisses. In the past they were classed as pre-Cambrian, but recent detailed work (Hawkes, 1941) indicates that at least part of them are of Paleozoic age, recrystallized and in part granitized into high-grade metamorphics. Workers have searched for the roots of the Taconic thrust plate in the Green Mountain schists; tentative correlations by Prindle and Knopf (1932) in northern Massachusetts and by Hawkes (1941) in central Vermont are discussed in the section on "Site of deposition".

According to Cady (1945) the Vermont and Champlain valleys form a geologic unit underlain by Cambro-Ordovician limestone and dolomite, with quartzites near the base and thick shales at the top. These rocks are cut by several large thrust faults; near the northern Taconic area they form a synclinorium which plunges gently southward and is complicated by much minor folding and some faulting.

Keith (1923; 1932; 1933) divided the Champlain-Vermont Valley rocks into three sequences deposited in different basins and now separated by major thrust faults. Cady's work shows, however, that the rocks all belong to one sequence connecting normally with that in the Hudson and Mohawk valleys and exhibiting normal lateral gradation.

The Adirondack massif is a pre-Cambrian body unconformably overlain by Paleozoic rocks of the Valley sequence. The eastern part of the Adirondacks and the western Champlain Valley are cut by normal faults trending generally northeast (Cushing and Ruedemann, 1914; Quinn, 1933).

PREVIOUS WORK

The true relation of the Taconic rocks to their surroundings has been an open question for many years. The original "Taconic Question" was concerned with the validity of large-scale stratigraphic sequences dated by a few fossils. Interpretations were repeatedly upset. Some of the early papers (Hunt, 1883–1885; 1887) seem little more than oratory; others (Emmons, 1844; Dana, 1887) were more practical. For a historical account the reader is referred to the chapter on the Taconic Question (Merrill, 1924).

Walcott, making the first modern approach, reviewed (1887) Emmons' and Dana's ideas and reported "middle Cambrian, or Georgian" fossils from typical "upper Taconic" rocks in Washington County, N. Y. He discussed (1888) the age of various rocks in the Taconic Mountains and called the Taconic slates "middle Cambrian", the limestones "Calciferous, Chazy, and Trenton". He refuted Emmons' ideas, pointing out Emmons' failure to note the thrust through Bald Mountain and its disturbance of the sequence. Finally he proposed to reject the name Taconic, considering it "based on error and misconception originally, and used in an erroneous manner since . . .".

By 1890 Walcott had reclassified his "middle Cambrian or Georgian" into its present position as the lower Cambrian. Soon after that, Dale began his work on the Rensselaer grit plateau (1894), the slate belt of New York and Vermont (1899), and Washington and Rensselaer counties (1904). For the slate belt, which adjoins the present area on the southwest, Dale set up a complete stratigraphic sequence. In correlating the important units of Dale's sequence with rocks in the Saratoga district, Cushing and Ruedemann (1914) affixed the formational names which have since been current (Table 1).

Dale considered the Taconic rocks unconformably overlain by the surrounding limestones. Ruedemann suggested, however, that the outlier (actually a re-entrant) of limestone at Hyde Manor, described also by Dale, was a fenster. He said, "It is there quite probable that the whole folded plate of Cambric rocks has been pushed along a slightly inclined fault plane from the east over the lower Siluric rocks" (1909, p. 190). This is the first formal recognition of the Taconic thrust.

By 1914 Taconic students recognized a rational stratigraphic sequence supported by fossils from many localities and by extensive field work in the slate belt and eastern New York. Although the individual lower Cambrian formations had yielded no key fossils, the stratigraphic sequence set up by Dale and Ruedemann had been checked repeatedly. No detailed maps had been published of the Taconic area except for Ruedemann's map of the Saratoga district. Dale's map of the slate belt is generalized with the Cambrian and Ordovician separated but not subdivided.

Keith (1923; 1932) discussed the stratigraphy and structure in the northern Taconic area and Champlain Valley, giving the three-sequence interpretation of the Valley rocks and his interpretation of the Taconic sequence. In 1933 he published a fault map of the northern Taconic area, without detailed stratigraphy, showing a complex net of faults covering most of the area. Keith's sequence bears no relation to that of the slate belt (Table 1), although his area included localities discussed and cross sectioned by Dale.

In the Taconic quadrangle of Vermont and Massachusetts Prindle and Knopf (1932) found a Taconic sequence similar in part to that in the Albany and Saratoga districts. Larrabee (1939–1940) mapped the commercial slate belt in detail and corroborated the Dale-Ruedemann sequence. His map shows, besides the Taconic thrust, only a few short faults with northeastern trend, similar to the northeasterly normal faults along the eastern margin of the Adirondacks (Quinn, 1933).

When the present study was undertaken the only available detailed maps of the Taconic area in Vermont were those covering the Taconic quadrangle and the slate belt. The Taconic thrust was variously denied, connected northward with Logan's Line (the St. Lawrence thrust), or looped around the northern end of the Taconic Range. The stratigraphic sequence set up in the most recent work, by Keith, offered no basis for correlation with that used by Larrabee, Cushing and Ruedemann, and Dale, all of whom agreed. The northern end of the Taconic area posed and offered the best approach to two fundamental problems: (1) What is the stratigraphic sequence in the Taconic rocks? and (2) what and where is the Taconic thrust in this region?

The results of the writer's study of these problems are given in this paper. The writer agrees with Merrill (1924, p. 605):

> "As he [Elkanah Billings] understood the matter at the time of writing [1871] some of the Taconic rocks were certainly more ancient than the Potsdam [basal upper Cambrian], while others might be of the same age, and perhaps some of them more recent. The details, he felt, had not yet been worked out, and on account of the extremely complicated structure of the region, he ventured to say that no man at that time living would ever see a perfect map of the Taconic region. The present indications are favorable to this view of the subject."

STRATIGRAPHY

GENERAL

The rocks in the area are part of the Cambro-Ordovician argillaceous terrane extending south and southwestward into Massachusetts and eastern New York. Detailed studies have been made of the region around Williamstown, Mass. (Prindle and Knopf, 1932); the western margin of the terrane in the Albany and Saratoga districts (Cushing and Ruedemann, 1914; Ruedemann, 1930); the slate belt (Dale, 1899; Larrabee, 1939–1940); and the northern end of the terrane (Keith, 1932; 1933).

The writer concludes that the rocks of the area belong to the Taconic sequence which comprises rocks from all the areas named above, and that definite correlations can be made, allowing for lateral gradation. He disagrees, therefore, with Keith, whose stratigraphic section for this area bears no relation to the others (Table 1).

The sequence in the northern Taconic area consists of lower Cambrian formations locally overlain by a thin series of middle Ordovician rocks. Fossils have been found in the Cambrian Mettawee and Schodack formations and in the Ordovician Normanskill series (Walcott, 1890; Dale, 1899, p. 182, 185, 189, and map; Cushing and Ruedemann, 1914; Ruedemann, 1930; and Schuchert, 1937). The lower Cambrian fossils do not include any formation-index species. The Normanskill series is dated as Chazy-Black River (Ruedemann and Wilson, 1936, p. 1549).

On the western side of the area the Cambrian formations are quite thin, and only the Bomoseen grit exceeds 250 feet. The whole Cambrian column is probably less

TABLE 1.—*Comparative stratigraphic chart of the Taconic sequence*

	Rensselaer County Dale, 1904	Slate Belt Dale, 1899	Slate Belt Larrabee, 1936 (names from Ruedemann, 1914)	Northern Taconic Area Kaiser, 1945	Northern Taconic Area Keith, 1932
Ordovician		Hudson shales	Normanskill formation	Normanskill formation	
Lower Cambrian		Ferruginous quartzite. 25–100 feet	Zion Hill quartzite	Zion Hill quartzite	
	J: greenish shale. 50 feet			Wallace Ledge slate: green and purple gritty slate	
	I: black shale with thin limestone and calcareous quartzite. 20–200 feet	Cambrian black shale. 50–200 feet	Schodack shales	Schodack slate: black slate, intermittent gray slate and limestone	Black slate (Hooker) Limestone (Beebe) Purple and green slate (Bull) Quartzite (Barker) Purple and green slate (Hubbardton) Green phyllite (Stiles) Dark-gray phyllite (Brezee)
		Black patch grit. 10–40 feet	Eddy Hill grit	Eddy Hill grit: thin-bedded quartzite	
	H: green, red, purple shale; calcareous quartzite. 25–100 feet	Cambrian roofing slates. 200–240 feet	Mettawee slates	Mettawee slate: purple and green slates	
	G: granular quartzite. 10–40 feet				
	F: olive grit. 18–50 feet	Olive grit. 50–200 feet	Bomoseen grit	Bomoseen grit: olive grit and sandy slate; quartzite lenses	

than 1000 feet thick in the slate belt, but on the eastern side it is believed to be considerably thicker. (*See* section on Berkshire schist and Bird Mountain grit.) The Ordovician formations, part of a clastic series which in the Saratoga district reaches a thickness of 1500 feet, are only locally present.

Only approximate figures can be given for thickness because of intense crumpling. For example, the Mettawee slate has very diverse types of outcrop pattern. Near the north end of Bomoseen Lake it covers several square miles, while east of Carver Falls it crops out on a hillside in a narrow band flanked by the adjacent formation (Pl. 1).

BOMOSEEN GRIT

This is a dense hard medium- or fine-grained impure quartzite with spangles of hematite and graphite. It weathers reddish brown or light red but is olive on fresh surfaces. Commonly this rock forms low rounded exposures or is covered by very thin soil.

According to Dale (1899) the Bomoseen grit consists largely of quartz with plagioclase and a little microcline, and a matrix of sericite, calcite, and secondary quartz. Larrabee (1939) reports that thin beds of coarse purple and green slates occur in the slate belt.

Between Fair Haven and Hydeville the formation is unmistakably a hard dense impure quartzite. Near Inman Pond north of Fair Haven the rock beneath the Mettawee formation is hard and quartzose but has a larger proportion of slaty matrix so that its cleavage is somewhat better though still rough. This coarse sandy slate occurs also farther north between Horton Pond and Roach Pond and again in the area east of Keeler Pond. These rocks have been correlated with the Bomoseen grit because the Mettawee has apparently its normal character, but they may be sandy basal beds of the Mettawee formation.

Dale called this formation the Olive grit. Its thickness in the slate belt he gave as 50–200 feet exposed, this being the lowest formation in that area. He assigned it a thickness of 18–50 feet in the Rensselaer district, where it is underlain by 150–800 feet of green and red shale and quartzite, which correspond to the Nassau formation as named by Ruedemann in the Albany district (1930).

As shown on the maps of this area and of Larrabee's area, the Bomoseen grit forms the base of the thrust plate along its western side as far north as the upper end of Bomoseen Lake. Farther north the relations are not so clear because another plate of probable Taconic rocks, chiefly black slate, comes between the main thrust and the Valley rocks. A klippe of Taconic rock south of Orwell near Sunset Lake was not mapped.

In the Taconic quadrangle Prindle and Knopf (1932) mapped a Cambrian graywacke overlain by purple and green slate. This graywacke may be continuous with the Bomoseen grit. The stratigraphic position of the Rensselaer grit (Dale, 1894) is still doubtful, but it probably also belongs to this formation, as indicated on the map of Prindle and Knopf (1932).

METTAWEE SLATE

The Mettawee formation is composed of fine-grained soft purple and green slate with local thin layers of quartzite. Many varieties occur (Dale, 1899, p. 226–277;

Larrabee, 1939–1940). Dale's analyses show that total iron content is very nearly the same in both the purple and the unfading green slate. However, in the former ferric oxide, as disseminated hematite, predominates; in the latter ferrous oxide. The sharp boundaries between color types, which trend both along and across bedding, are unexplained. The purple slate occurs largely in the center of the formation, with a thick layer of green slate above and below. The formation as a whole is soft and in most places underlies valleys, including nearly all the lakes in the area. Along the eastern side of the Taconic Range, however, slightly more advanced metamorphism produced fine-grained phyllites more resistant to weathering. The formation probably thickens eastward, but crumpling precludes measurement.

Dale called this formation the Cambrian roofing slates and gave its thickness as 200–240 feet. Larrabee's figures are 90–200 feet. In Dale's Rensselaer County section, formation H comprises 25–100 feet of green, red, and purple shales with calcareous quartzite layers. This formation was named the Troy shale by Ruedemann in his Albany report (1930). Since it stands in the same position as the Mettawee formation—between the Olive grit and the black (Schodack) shale—they are probably the same.

In the Rensselaer County area the Diamond Rock quartzite, 10–40 feet thick, lies between the Olive grit and the purple and green slate. This formation is either absent or not sufficiently distinctive to be separated in the present area. Larrabee mapped a limestone conglomerate in the Mettawee formation of the slate belt. The only limestone layer in the present area occurs above the quartzites which cap the Mettawee slate and which are at least in part synonymous with the Eddy Hill grit, and it is therefore part of the Schodack formation.

EDDY HILL GRIT

Larrabee (1939, p. 51) describes this formation as a "dark grayish grit composed of quartz grains in a matrix of calcareous material. Some black shaly patches are to be found—". He gave its thickness as 40 feet; Dale, who called it the Black Patch grit, as 10–40 feet.

In the Scotch Hill district at the north end of the slate belt the Eddy Hill formation consists of a narrow zone of thin-bedded dark quartzites capping the purple and green slate. Farther north, however, in the area between Glen Lake and Cedar Point of Bomoseen Lake, the grit is apparently missing, and a 10-foot layer of limestone separates the black Schodack slate above from the green Mettawee slate below. East of Hubbardton the sequence is as follows: (1) main body of the Mettawee formation; (2) 50 feet of dense pink quartzite; (3) a 50-foot covered area; (4) about 50 feet of greenish-gray slate containing many thin dark quartzite layers; (5) 100 feet or more of medium- and dark-gray slate containing a limestone conglomerate; and (6) black Schodack slate. The writer correlates the zone of dark thin-bedded quartzite with the Eddy Hill grit, and the limestone conglomerate with the limestone member of the Schodack formation. In this interpretation the pink quartzite layer is a lens in the upper part of the Mettawee formation; the gray slate containing the limestone is the lower part of the Schodack formation.

Nothing corresponding to the Eddy Hill grit is mentioned in the Rensselaer or Albany sections.

SCHODACK FORMATION

The Schodack formation is composed of gray and black slates with interbedded thin calcareous quartzite beds and an intermittent limestone member. The cleavage of the slate is generally poor but varies from pencil cleavage to good slaty cleavage. The black slate is typically coal black, weathering to rusty brown or black or locally to white. Bedding is present but inconspicuous except in a few localities, notably the long road cut north of Roach Pond and that just south of Glen Lake. The gray slate generally shows no bedding; its cleavage varies like that of the black slate.

In the southern Scotch Hill district and just northeast of Glen Lake where this formation has the narrowest outcrop, it is entirely black slate, and the limestone member occurs between the black slate and the purple and green slate, or between the black slate and the Eddy Hill grit. East of Hubbardton a thick layer of gray slate separates the black slate above from the Eddy Hill grit below, and the limestone occurs within the layer of gray slate. The gray slate is therefore intermittent, while at least the bulk of the black slate is present everywhere.

The limestone member varies from a massive limestone bed 50 feet thick to a thin limestone conglomerate of which perhaps two-thirds is shaly material; this in turn lenses out in places. The limestone is dark gray on fresh surfaces and weathers to brownish buff. It is fine-grained and contains numerous veinlets of quartz and calcite which weather in relief. Its topographic expression in low hills and ridges is well shown just east of the southern end of Bomoseen Lake.

The conglomeratic variety occurs east of Hubbardton and east of the southern end of Bomoseen Lake. The massive variety is well exposed just east of Fair Haven on the north side of the road, where it crops out over an area about 200 yards in diameter; and 2 miles northeast of Hubbardton where it covers a larger area. In both places the bedding is nearly horizontal, which fact explains the large area of exposure.

Wing (Dana, 1877b) reported an Ordovician trilobite, *Trinucleus concentricus* (now *Cryptolithus tesselatus*), in a locality "ten miles southeast of Sudbury in Hubbardton, in a limestone band sixty yards wide in the heart of the great central belt of slates. ..." This trilobite is the guide fossil for the upper part of the Glens Falls (Trenton) limestone in the Valley sequence. The limestone band referred to must be that northeast of Hubbardton village, which was at first interpreted as a fenster of Valley limestone under the Taconic thrust. Detailed study showed, however, that undoubted Schodack limestone can be traced almost continuously from a locality in which Walcott found Cambrian fossils into this area. Distribution of the black slate and of the probable Normanskill agrees with this interpretation. Cady (1945, p. 567, Pl. 10) interprets this limestone and another patch at the south end of Beebe Pond as fensters of Valley rocks. Until fossils are again found here the writer can only point out that this limestone can be traced for some distance in black slate which he identifies as Schodack, and that it closely resembles other exposures of known Schodack age.

Calcareous quartzite layers occur in the black slate but probably not at any single horizon, though they may be restricted to the lower part of that zone. Most of them

are less than 6 inches thick and composed of quartz grains with limonite-calcite matrix. They are full of narrow veinlets of quartz which weather in relief. The weathered rock is coated with a rusty porous shell which crumbles under the hammer.

Cambrian fossils have been found both in the limestone and in the calcareous quartzites. Walcott reported them about 2 miles northeast of Hubbardton (Dale, 1899, map). Dale's map also shows several other fossil localities in this formation. Schuchert (1937, p. 1038–1039) found trilobite fragments in the limestone northeast of Glen Lake and in the calcareous quartzite beds exposed in the road cut just south of Glen Lake.

Keith called the limestone member the Beebe limestone. Since Keith's interpretation is here rejected, the name has not been used. Dale called the formation as a whole the Cambrian black shale, 50–250 feet thick; Larrabee's figures are 20–200 feet. Formation I of Dale's Rensselaer County section, a black shale 20–200 feet thick with thin limestone and calcareous quartzite layers, is probably the Schodack formation.

A most puzzling question is that of the relations of the black slates which occur on Government Hill at the north end of the area and in the band on the north and east sides of the known Taconic rocks between Brandon and West Rutland. The Schodack black slates cannot be distinguished in the field from the Canajoharie black slates, which cap the Trenton limestone in the Valley sequence and are therefore to be expected where that limestone occurs.

Cady and the writer agreed that Canajoharie slate occurs in the area south of Sudbury, although the position of the boundary here is open to question. At Government Hill and southeastward, however, the black slate truncates the Valley limestone as far down as the upper Beekmantown, according to Cady (1945, p. 569). If the black slate is Canajoharie, it must either be faulted or else lie on an abrupt angular unconformity. The problem could not be solved structurally since small-scale structures are too complex; fossils have not been found since the shales are highly deformed. The following field relations, however, bear on the question.

(1) The Canajoharie slate, where it caps the Trenton limestone near Whiting and near Hortonville, is a black slate and contains no gray, purple, or green facies. The rocks on Government Hill, on the other hand, are partly gray, partly black; and purple and green slates occur just east of Sudbury, near the western edge of the black slate area. Although no quartzite nor limestone occurs between the black slate and the purple and green slate, both the Eddy Hill grit and the limestone member of the Schodack are intermittent.

(2) Just south of the black slate area, on the north side of Stiles and Castle mountains, occurs a well-banded hard gray rock, fine-grained but coarser than a shale, which strongly resembles those rocks called Normanskill farther south. In the lower part of this series is a ferruginous calcareous quartzite about 10 feet thick with quartz veins weathering in relief; this resembles the calcareous quartzite layers in the Normanskill at Glen Lake. Since bedding-cleavage intersections in the black slates plunge gently southward, they lie beneath these banded rocks if the sequence is normal.

(3) At several places a pinkish-gray massive quartzite 10–20 feet thick occurs between the black slate and the banded series. This may be the Zion Hill quartzite, which is variable in thickness.

After considering this evidence the writer mapped the black slate as Schodack, the banded rock as Normanskill, the intermittent quartzite as the Zion Hill formation, and the patch of purple and green slate as Mettawee. The series thus forms a thrust plate beneath the main Taconic thrust plate.

Cady (1945, p. 560) suggests, however, that the black slate is Canajoharie and that the Taconic thrust lies above it. On his map (1945, Pl. 10) the black slate in question is labelled as either Canajoharie or undifferentiated Taconic, and the fault is shown above the black slate. Because of the structural complexity the question will probably be solved only by fossils.

WALLACE LEDGE FORMATION

In the slate belt the Zion Hill quartzite lies directly on the black Schodack slate. This relation holds true also in the Scotch Hill district, at Glen Lake, and north of Stiles Mountain. In the Zion Hill district, however, a layer of colored slate intervenes between the Schodack slate and the thick quartzite which caps the several hills. The lower part of this layer is gritty purplish slate; the upper part, as exposed beneath the quartzite on the cliffed western side of Wallace Ledge, is a soft green slate with some purple. At the latter locality about 60 feet of slate is exposed. Comparison of outcrop areas suggests that the colored slate is about 100 feet thick. Since the lithology of this layer is distinct from those above and below, it is here set up as a separate formation, named for its best exposure on Wallace Ledge.

Formation J of Dale's Rensselaer County section, above the black shale, is a greenish shale 50 feet thick, which may correlate with the Wallace Ledge formation.

ZION HILL FORMATION

This formation is chiefly massive gray medium- or coarse-grained quartzite. Limonite spots are common, and the matrix contains calcite and siderite. Quartz and calcite veinlets of random orientation are common and stand in relief on weathered surfaces. The formation varies considerably in details of lithology and in thickness. In the Zion Hill district it is composed of two massive beds of quartzite separated by a thin layer of sandy shale. Layers of breccia and conglomerate, nodules of marcasite partly altered to limonite, limestone edgewise conglomerate, and black pebble conglomerate, which are reported by Larrabee (1939–1940) from the slate belt, were not seen in the present area.

The formation at Zion Hill and Wallace Ledge is about 80 feet thick. Larrabee's figure is 70 feet; Dale's, 25–100 feet. In many places the formation is absent, and the Normanskill formation lies directly upon the Schodack formation.

BERKSHIRE SCHIST AND BIRD MOUNTAIN GRIT

On Dale's map (1899) the eastern part of the Taconic Range is mapped as Berkshire schist of "Lower Silurian" (now Ordovician) age. This formation as mapped is substantially the same as Emmons' Magnesian or Talcose slates and as Dana's Hydromica schists. Dale believed that the Berkshire schist overlies unconformably the Cambro-Ordovician limestone and dolomite of the Vermont Valley, that it occupies the center of the Taconic synclinorium, and that the slight increase in

metamorphism indicates a difference in age. Since agreement now seems to be unanimous that the east side of the Taconic Range is separated by a fault from the marbles of the Vermont Valley, this reasoning is not valid.

Larrabee mapped the eastern part of the slate belt as "Rowe schist", greenish and purple phyllite, the boundary of which nearly coincides with that of Dale's Berkshire schist. Although Larrabee does not definitely date this rock, he infers that it is at least in part the same as the Mettawee slate. After the writer had studied the Taconic sequence in both the western and central parts of the area, he then studied the rocks in the eastern part, those mapped as Berkshire schist by Dale. Field evidence indicated that the Hubbardton Hills are underlain by the Mettawee and Schodack formation, either originally thicker than to the west or thickened by crumpling. Only Cambrian formations, therefore, occur on the eastern side of the range, north of the Castleton Valley.

South of that valley the writer did only limited reconnaissance, but since there is no immediate prospect of further work there a brief discussion is given.

Of the high hills which overlook Castleton Valley from the south the most striking is Bird Mountain. It is composed chiefly of quartzite and conglomerate and has been discussed by Dale and others. According to Dale (1900) the exposed rock consists of about 500 feet of grit and conglomerate with interbedded schist. The series is coarser toward the top with pebbles of limestone and calcareous quartzite as large as 3 by 5 inches. Iron oxide is common. About 100 feet of the series is phyllite.

That this series is part of the Taconic sequence is indicated by the fact that the purple and green phyllite which crops out in the central and eastern part of the Castleton Valley occurs also on the north foot of Bird Mountain and on the col south of it. Dale mentions these as occurrences of purple and green Berkshire schist, but they are probably Mettawee slate of slightly increased metamorphic grade, since the known Taconic Ordovician contains green slates but no purple and green mixture. These phyllites underlie the Bird Mountain grit and crop out on Ben Slide on Herrick Mountain where they form a cliff about 200 feet high. Total thickness is perhaps greater than this judging from the fact that south of Bird Mountain green phyllite crops out several hundred feet lower.

These facts indicate that the Berkshire schist is composed of the Mettawee and Schodack formations, and that the Bird Mountain grit is a thick facies of the Zion Hill formation.

NORMANSKILL FORMATION

This formation in the slate belt consists, according to Dale (1899) and Larrabee (1939–1940), of a zone of grit about 300 feet thick composed of medium and coarse quartz grains in a calcareous and argillaceous matrix, and a zone of graywacke-quartzite-slate about 1250 feet thick. It is of Chazy-Black River age (Ruedemann and Wilson, 1936, p. 1549).

In the present area the rocks called Normanskill are characterized by marked banding, medium grain, generally calcareous cement, and hardness. Beds of ferruginous calcareous quartzite are common. The best exposures are on the east

side of Glen Lake and just southeast of Beebe Pond where the rocks lie in an overturned syncline. Probably no more than 300 feet is present in this area.

SUMMARY OF STRATIGRAPHIC RELATIONS

Plate 1 shows that the various formations crop out chiefly in continuous bands with simple pattern and in places make contour patterns on hillsides, that individual formations are thin enough to show any significant offsetting, and that the sequence of the formations is consistent. Thus the stratigraphic succession is in reality undisturbed, the large-scale structural picture simple, and the sequence solvable by the usual methods. The sequence worked out agrees with that of the slate belt which, in turn, correlates with the Taconic sequence in the Saratoga district (Cushing and Ruedemann, 1914; Larrabee, 1939, p. 48). The names established by Cushing and Ruedemann apply, therefore, in the northern Taconic area.

Keith's interpretation of the geology of the area gained currency by its inclusion in the International Geological Congress guidebook for New England (Keith, 1933). Since his is the most recent study of the area, his results are compared with those of the writer (Table 1). The discrepancy between his sequence and the writer's is complete both in the formations and in their order.

Assuming that the geographic names used by Keith indicate type localities, we may compare the positions in the two sequences of the rock at each locality. The Brezee phyllite is probably the gray slate cropping out near Brezee Creek in the northern part of the area; this is now mapped as Normanskill. The Stiles phyllite is probably that exposed on the west side of Stiles Mountain, now mapped as Mettawee. The Hubbardton slate is also Mettawee, which underlies Hubbardton Corners. The Barker quartzite, which must be that exposed on Barker Hill, is Zion Hill quartzite. If the quartzite shown on Keith's sketch map (1933, Pl. 8) is the Barker quartzite, he has also included portions of Bomoseen grit and Eddy Hill grit. The Bull slate is Mettawee slate, which underlies Bull Hill. The only limestone near Beebe Pond, which must be the Beebe limestone, is part of the Schodack formation. Finally the slate on Hooker Hill, and therefore the Hooker slate, is part of the Schodack formation. This comparison indicates that Keith classified all quartzites into one formation, while making two or more formations out of different exposures of the Mettawee formation. Part of the evidence for his faults stemmed perhaps from the exigencies of this interpretation.

Thus Keith's sequence and the writer's sequence are quite incompatible. Since the formations can be traced into the slate belt and since the slate belt and the Saratoga district have been studied in great detail, Keith's sequence and formation names are rejected in favor of the sequence established by Dale and named by Cushing and Ruedemann.

SITE OF DEPOSITION

The Cambrian section of the northern Taconic area is quite similar in character and thickness to that of Rensselaer County some 50 miles distant. The Normanskill likewise extends between these two areas and beyond to the lower Hudson

River region (Ruedemann and Wilson, 1936, Fig. 1). A similar section occurs in the Taconic quadrangle (Prindle and Knopf, 1932; 1933, Pl. 14).

In the western or Valley sequence no lower Cambrian is found in the Mohawk Valley and western Champlain areas where the basal Potsdam sandstone is upper Cambrian. Lower Cambrian rocks do occur, however, both in the Vermont Valley and in northwestern Vermont; according to Cady (1945) these may be correlated. They form a lower Cambrian sequence of quartzites and dolomites extending from the Canadian border at least as far south as Williamstown, Mass.

The marked differences between this sequence and that of the Taconic area and the differences in the two faunas are the principal reasons for the theory that the Taconic rocks originated in a separate basin and were thrust over the rocks of the Valley sequence. The Normanskill formation, of Chazy age, is accepted as part of the Taconic sequence since it is clearly infolded with Cambrian formations. Ruedemann also placed the Snake Hill shale of Trenton age, which occurs in the upper Hudson Valley, in the Taconic sequence; this is questioned by Kay (1937) who interprets the formation as an eastern sandy equivalent of the Canajoharie shale, formed in the same basin.

If the Taconic sequence is foreign, where are its roots? Paleogeographic considerations require an eastern rather than a western source. Since the rocks to the east are metamorphosed little detailed evidence is available for correlation. A thick clastic series of possible Cambrian age occurs on the summit and upper east flank of the Green Mountains, and Cambrian clastics are probably present in western New Hampshire; the roots of the Taconic body may lie in east-central Vermont or in New Hampshire.

In the Taconic quadrangle Prindle and Knopf (1932) tentatively correlated the Taconic rocks with schists in the Hoosac Range to the east (Fig. 1). These are probably equivalent to some of the central Vermont metamorphics. Hawkes (1941) subdivided the rocks in the clastic Green Mountain sequence of central Vermont and suggested that they belong to the Taconic sequence but did not attempt detailed correlation. Like Keith (1932, p. 404) he postulates a major structural break between the Green Mountain series and the Valley rocks, since the former lies in the east limb of an anticline, in the center of the range, while the latter lies in the west limb of an anticline on the west side of the range; yet there is great stratigraphic dissimilarity. He suggested that the structural break is the Taconic thrust and that the Green Mountain sequence is the root of the Taconic sequence, the whole having been thrust westward over the valley rocks and the two parts then completely separated by erosion of the Vermont Valley.

Definite correlation must await detailed mapping of large areas of the Taconic Range and of the Green Mountains.

STRUCTURE

MAP STRUCTURE

Because of the severe small-scale crumpling of the less competent rocks of this area, and because bedding is not everywhere visible, the large structures must usually be read from the pattern of formations as seen on the map. The simplicity

of this pattern indicates that the small-scale structures are the only intense ones, and that the large-scale structures are surprisingly simple. The western part of the range, an area 15 miles long and 5 miles wide with relief of about 600 feet, is underlain by a rock series no more than 1150 feet thick. This circumstance is amazing in a terrane considered extremely complex structurally. The spottiness of the map is due largely to topographic irregularities, for in most of the area the formations as a whole are nearly horizontal. Only in a few long narrow synclinal belts are there large-scale folds, for example in the belt running past the east end of Glen Lake. Otherwise the distribution of formations is governed by gentle structural irregularities such as the broad shallow structural basin within which most of the Zion Hill formation occurs and that north of Fair Haven in which Normanskill occurs.

Are there a great number of faults cutting these rocks as Keith's map (1933, Pl. 8) shows? Recognition of faults must depend either upon anomalies in stratigraphy or upon fault structures of some sort. Stratigraphic evidence suggests only one fault inside the Taconic thrust—the one along the northern edge of the area. In a belt about a mile wide on the southern side of this fault, and to a lesser extent farther south, most outcrops show extreme crumpling of bedding and dragging of cleavage. Irregular quartz veins are common, especially where the rocks contain considerable quartz as sand or cement. If these are evidence of dislocation, the whole terrane must be cut by closely spaced shears along which there was very little movement. More probably these veins are local developments as a result of crumpling. The steep southeastward-plunging linear structure locally present in these rocks is anomalous; it was probably produced during two periods of disturbance following different trends.

Probably the massive Bomoseen grit and Zion Hill quartzite controlled the structure. The attitude of the latter on Zion Hill, Barker Hill, and Wallace Ledge is instructive. In the first two localities the quartzite is nearly horizontal and unfolded but cut by irregular quartz veins. On Wallace Ledge it is broken along a small sharp fold overturned southwestward and plunging very gently south-southeastward. The dislocation is very slight, and no evidence of it could be found in the slate beneath; the quartzite is nearly horizontal except at the fold. This fold cannot be followed in either direction but is possibly reflected in the great disturbance of the black slate 2 miles south-southeast of Wallace Ledge.

SMALL-SCALE STRUCTURES

Distinct axial-plane foliation is exhibited by all slate and limestone of this area, by limestone and slate of the Valley sequence, and to a lesser extent by all but the most massive beds of the Bomoseen grit. The quartzites are commonly massive though cut by more or less irregular quartz veins. Throughout the area the foliation dips 20°–50° eastward and strikes between north and northeast, except in zones of intense disturbance where foliation is dragged into local east-west strikes and south dips. Linear structure produced chiefly by crumpling of the foliation surface is common in the slate. Usually it is parallel to the line of intersection of foliation and bedding, but some exceptions have been noted. For example, in the purple and green slate about half a mile east-southeast of Sudbury

village, bedding-foliation intersection is horizontal, but a strong lineation plunges 40° S. 65° E.

A notable feature in the Valley limestone surrounding the northern Taconic area is the lineation lying in the foliation planes and striking rather consistently near S. 60° E. This lineation, which looks like fine ruling, is parallel neither to structural axes in the limestone nor to the average position of the Taconic axes (Pl. 1, between Brandon and Sudbury). Its significance is not known, but it is possibly related to the thrusting. The limestones are too fine-grained for optical petrofabric work.

Fracture cleavage is found almost everywhere. Its attitude is only locally related directly to other features, for example in the banded slate north of Roach Pond and southeast of Beebe Pond where it is perpendicular to bedding-foliation intersection. In general the strike lies between north and northeast, the dip between vertical and steep west. No regular pattern of variation was detected. Dragging commonly indicates some displacement, both east side up and east side down, in which no pattern could be seen. Since it is later than the major folding and production of foliation it is probably a late relaxational structure.

Practically all the quartzite contains quartz veins, which exhibit random orientation and are undoubtedly local fractures filled with quartz of local origin.

METAMORPHISM

The argillaceous rocks of this area are moderately metamorphosed to slate in the western and central part of the area and to phyllite in the eastern part. Acicular hornblende or actinolite is the highest-grade mineral developed; chlorite and sericite are common, but no biotite or garnet occurs. The few late dikes show no exogenous effects.

The occurrence of more than one period of disturbance is indicated by anomalous linear structures and by folded foliation. Normally lineation is parallel to the bedding-foliation intersection, which in turn must be parallel to the axial line of the fold related to the foliation. One of the most striking examples of an anomalous relation occurs in the area south and southeast of Zion Hill and Barker Hill. Here the distribution of formations indicates that the beds as a whole are nearly horizontal, yet both lineation and bedding-cleavage intersections dip steeply southward and locally are vertical. The most probable explanation is that after the first folding produced foliation, and axial lines plunging gently south or southeast, a second compression locally crumpled the rocks along easterly axes without producing any foliation.

Foliation is in many places dragged like bedding into flexures with generally a southeast trend. The presence of foliation in a probable fault breccia on the west side of the area suggests that foliation has locally been produced after thrusting.

THE TACONIC THRUST

REVIEW OF PREVIOUS WORK

Walcott, the first modern worker in the area, noted (1888) the fault at Bald Mountain, N. Y., and understood that the sequence was disturbed there, but the

concept of long-range thrusting did not exist at that time. Dale's (1899) theory that the Taconic rocks lie unconformably beneath the Valley limestones has been discussed in the section on "Berkshire schist and Bird Mountain grit."

Ruedemann (1909) first suggested that the Taconic slates were faulted along a low-angle thrust and that limestone areas within the slates were therefore fensters. In 1911 this idea was current, and Dale (1912–1913), to test it, drilled several holes near Hyde Manor where bands of slate alternate with bands of limestone, the whole being a series of isoclinal folds. If the rocks were unconformable the slate would be beneath the limestone, and in this case a band of limestone flanked on both sides by slate should be the core of a syncline. A hole drilled into the limestone parallel to the axial plane of the fold should therefore encounter slate at the bottom of the fold. The hole upon which Dale laid most weight encountered slate at shallow depth, and Dale therefore concluded that the slate unconformably underlies the limestone. Since present workers agree that the slate is on top of the limestone here, Dale's experiment is now of only historical interest. The result of the drilling can be explained by the fact that foliation dips are quite variable; the hole probably went off the warped axial plane into the side of the fold where it entered the slate.

Keith (1932; 1933) described the Taconic thrust and placed the roots of the thrust plate far to the east. Prindle and Knopf also pictured a Taconic thrust plate with its root probably in the Hoosac Mountain schists to the east. The International Congress guidebook for New England includes Keith's map and a summary of knowledge of the Taconic series and of the Taconic thrust in Massachusetts and the Hudson Valley (Keith, 1933, also p. 10–20, 52, 87–93, Pls. 8, 14). Larrabee's map (1939) shows the Taconic thrust west of the slate belt.

STRUCTURAL EVIDENCE

Structural evidence for the Taconic thrust in this area is not decisive. The thrust has been mapped by the use of stratigraphy; where doubt exists as to stratigraphic relations, for example in the black slates of the northern end of the area, doubt also exists as to the position of the thrust.

Detailed structural evidence is scarce. Foliation is disturbed in many places; in a small fenster in the black slate at the northern end of the area, 2 miles southwest of Brandon, the limestone is dragged westward along an axis striking S. 20° W. Such disturbance, however, is not restricted to the vicinity of the fault. Fracture cleavage is more intense in the eastern part of the area because of greater metamorphism there. In banded slate north of Roach Pond fracture cleavage is more evident toward the west, which is toward the outcrop of the thrust, but this is the only case of such a relation. Calcite and quartz-vein distribution is chiefly dependent upon rock types rather than structure; the more brittle formations have more filled fractures.

Larrabee (1939, map, p. 49) mapped a belt of rock adjoining the contact between the Taconic and Valley rocks on the western side of the slate belt as Eddy Hill grit. The writer considers this a fault breccia. It is composed chiefly of silicified fragments of black slate, well cemented by quartz and calcite, and lies beneath the Bomoseen grit which here forms the hanging wall of the thrust. This breccia appears also along the fault west of Brezee Pond where the purple and green slate

is apparently in fault contact with the black slate, and the breccia consists chiefly of fragments of green slate. The approximate extent of this breccia, where known, is shown on Plate 1.

STRATIGRAPHIC EVIDENCE

Stratigraphic evidence for the thrust is as follows: (1) contact of various Taconic beds with rock of the Valley sequence, (2) contact of various Valley beds with rock of the Taconic sequence, (3) large-scale structural relations of the two terranes, (4) occurrence of fensters of Valley rocks and of klippen of Taconic rocks, and (5) paleogeographic relations.

(1) On the west side of the area, Bomoseen grit, the lowest local Taconic formation, is in contact with Valley limestone and slate. On the northern boundary the Schodack and Mettawee formations are in the same position.

(2) On the western and northern boundaries, the Valley rocks at the Taconic contact are the Trenton and Chazy formations. On the northeastern and eastern boundaries the rocks at the contact are Chazy and Beekmantown. If the black slate around the northern and eastern margin of the area is interpreted as Canajoharie, however, most of this evidence is disposed of.

(3) The Valley rocks form a large-scale synclinorium plunging very gently southward under the Taconic terrane. The Taconic rocks form a nearly flat sheet which lies on the Valley synclinorium. The structural pattern therefore changes at the contact between the two terranes.

(4) The limestone exposures in the black slate at the north end of the area are probably fensters. The klippen of Bomoseen grit west of the main Taconic plate (Cady, 1945, Pl. 10) lie on Canajoharie slate.

(5) As pointed out in the discussion of "Site of deposition", the lower Cambrian portion of the Valley sequence is a quartzite-dolomite series which extends from northwestern Vermont down the Vermont Valley into Massachusetts. The lower Cambrian portion of the Taconic sequence is largely slate with some quartzite and only one thin bed of limestone. That these two series are equivalent is of course not proved, but they constitute the visible portion of lower Cambrian rocks below the later rocks in each case, and each series has considerable extent. Also most of the Taconic Normanskill formation is of Chazy age and is to be compared with the Chazy limestone series in the Valley sequence. It seems logical to conclude, therefore, that these two series were deposited in separate basins and that they have since been brought together by thrusting.

The occurrence of fensters and klippen and the paleogeographic relations thus constitute the clearest evidences of a thrust and in collaboration with the others indicate that the Taconic terrane is exotic.

SUMMARY OF CONCLUSIONS

The stratigraphic sequence of the Taconic rocks closely resembles that of the Vermont slate belt and the Saratoga and Albany districts; the units of this sequence were named by Cushing and Ruedemann. The sequence which Keith set up does not accord with field facts and is rejected.

The Taconic slates are thrust over the limestone-dolomite-slate series of the Champlain and Vermont valleys. Besides this Taconic thrust only one subsidiary fault was recognized, and Keith's internal faults were not substantiated.

The position of the thrust around the north end of the area is in doubt but lies probably between the black slate and the dolomite. The existence of the thrust, however, is believed to be demonstrated.

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New Jersey Zinc Company, Austinville, Va.

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STRUCTURE

40 — Strike and dip of foliation.

10 → — Trend and pitch of linear structure, which is intersection of bedding and foliation unless labelled otherwise.

10 Lin. → — Lineation in foliation plane of limestone.

Scale 1/62500

1 0 1 2 3 Miles

Contour interval 20 feet

LEGEND

VALLEY SEQUENCE

V — Valley limestone, dolomite, slate, and quartzite — CAMBRO-ORDOVICIAN

N — Normanskill slate — MIDDLE ORDOVICIAN

Calc. Qtzt: Calcareous quartzite

TACONIC SEQUENCE

Z — Zion Hill quartzite

W — Wallace Ledge slate

S — Schodack slate

Limestone member

E — Eddy Hill grit

M — Mettawee slate

B — Bomoseen grit

LOWER CAMBRIAN

Thrust fault, T indicates overthrust side

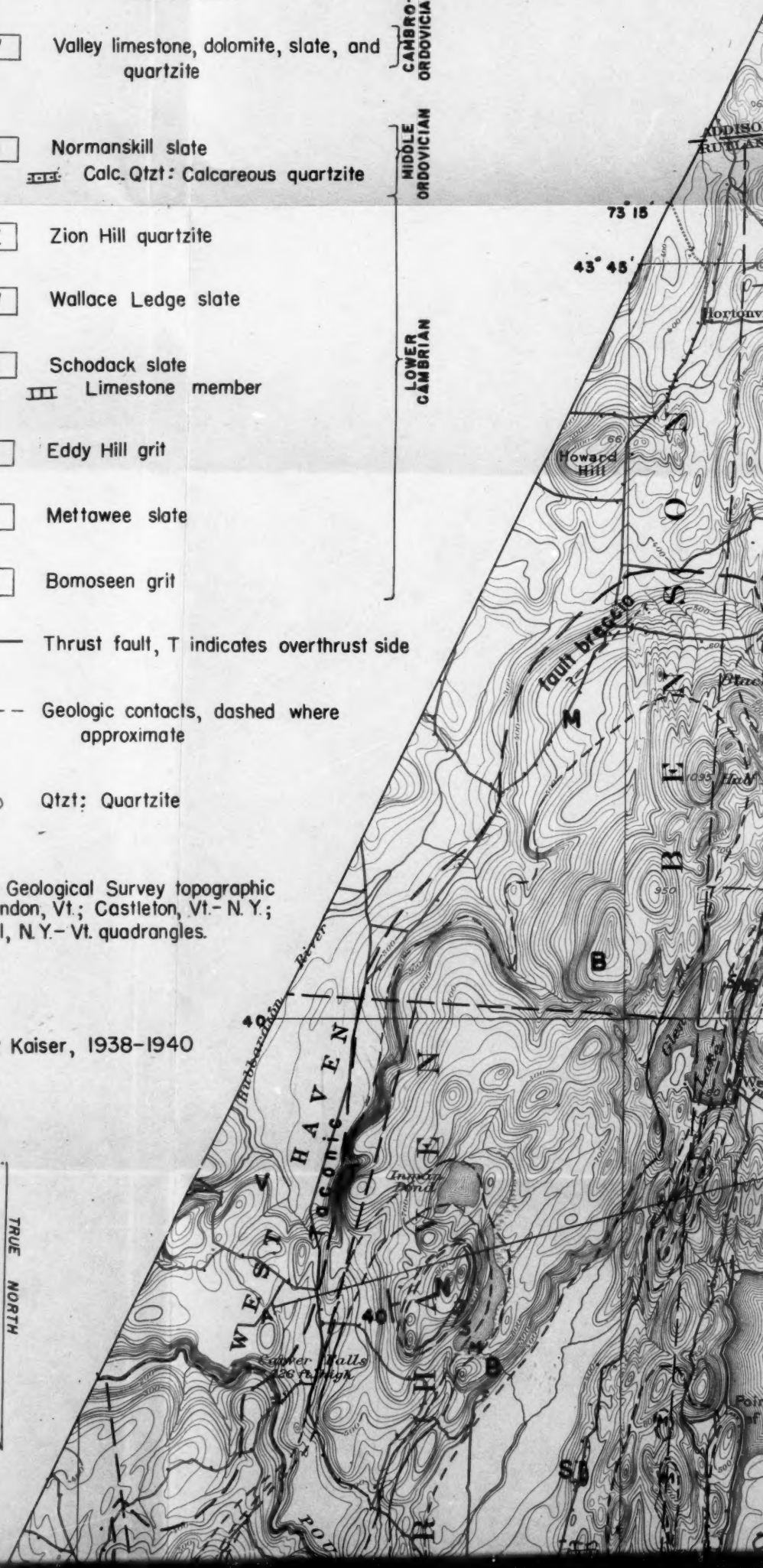
Geologic contacts, dashed where approximate

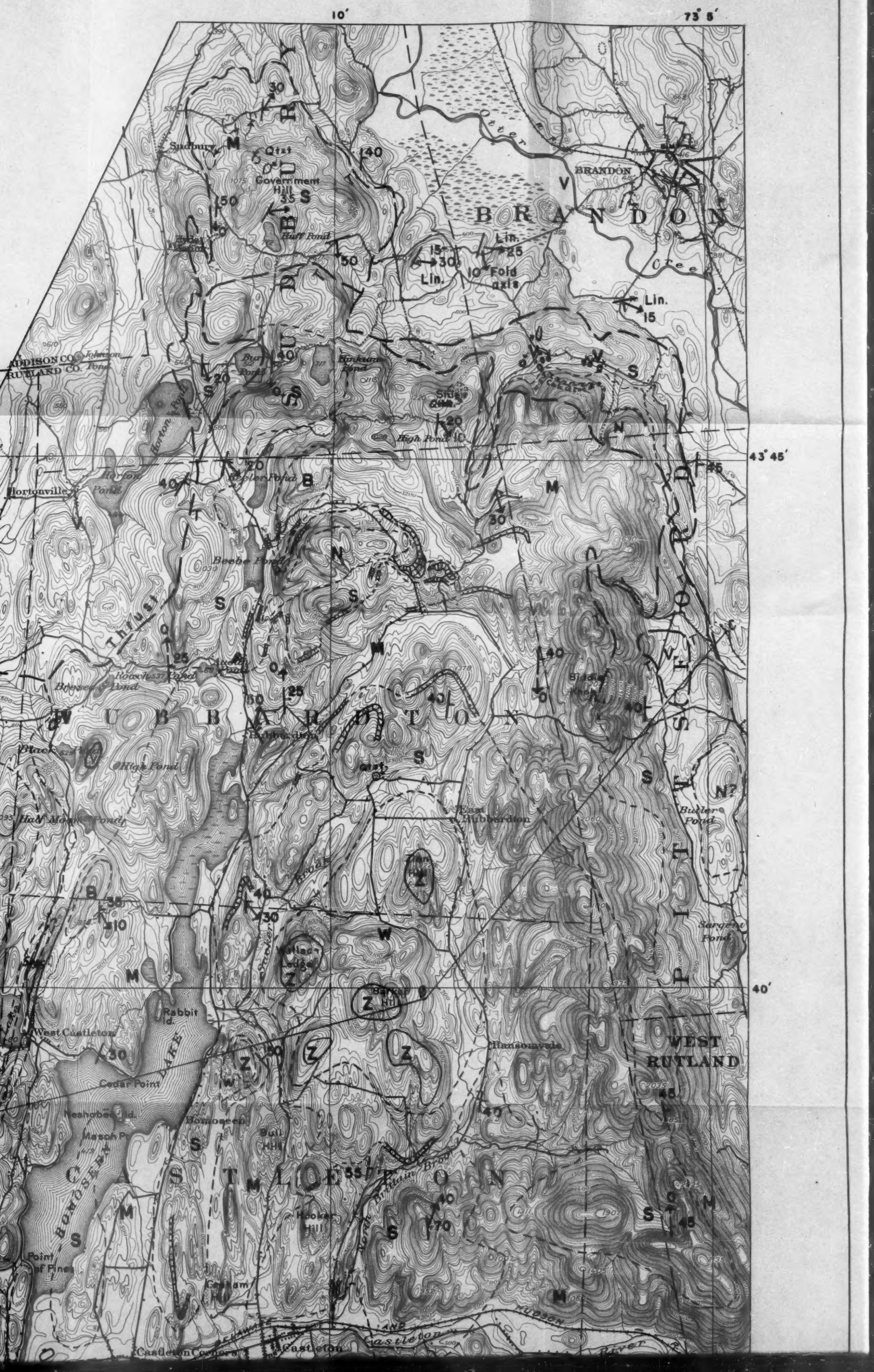
Qtzt: Quartzite

Base from U. S. Geological Survey topographic maps of Brandon, Vt.; Castleton, Vt.– N. Y.; and Whitehall, N. Y.– Vt. quadrangles.

Geology by E. P. Kaiser, 1938–1940

16° MAGNETIC 1945 NORTH — TRUE NORTH




10'
73° 8'
43° 45'
40'
BRANDON
Otter Cree
Sudbury
Government Hill
Buff Pond
Lin.
Fold axis
ADDISON CO.
RUTLAND CO.
Johnson Pond
Burham Pond
Horton Pond
Meyler Pond
Hortonville
High Pond
Beebe Pond
Thrust
Hooch Pond
Bloser Pond
Black Pond
Hall Meadow Pond
Broad
Ballard Hill
Barrett Hill
Rabbit Id.
West Castleton
Cedar Point
Lake
Teshobee Id.
Mason Pt.
Bull Hill
Hooker Hill
Point of Pines
Catlam Hill
Castleton Corners
Castleton
Castleton River
Hudson
Canal
Ransomville
WEST RUTLAND
East Hubbardton
Butler Pond
Sargent Pond
Brittain Brook
Bloser Brook
Hoosic
SUDBURY
HUBBARDTON
CASTLETON

Limestone member

E — Eddy Hill grit

M — Mettawee slate

B — Bomoseen grit

Thrust fault, T indicates overthrust side

Geologic contacts, dashed where approximate

Qtzt: Quartzite

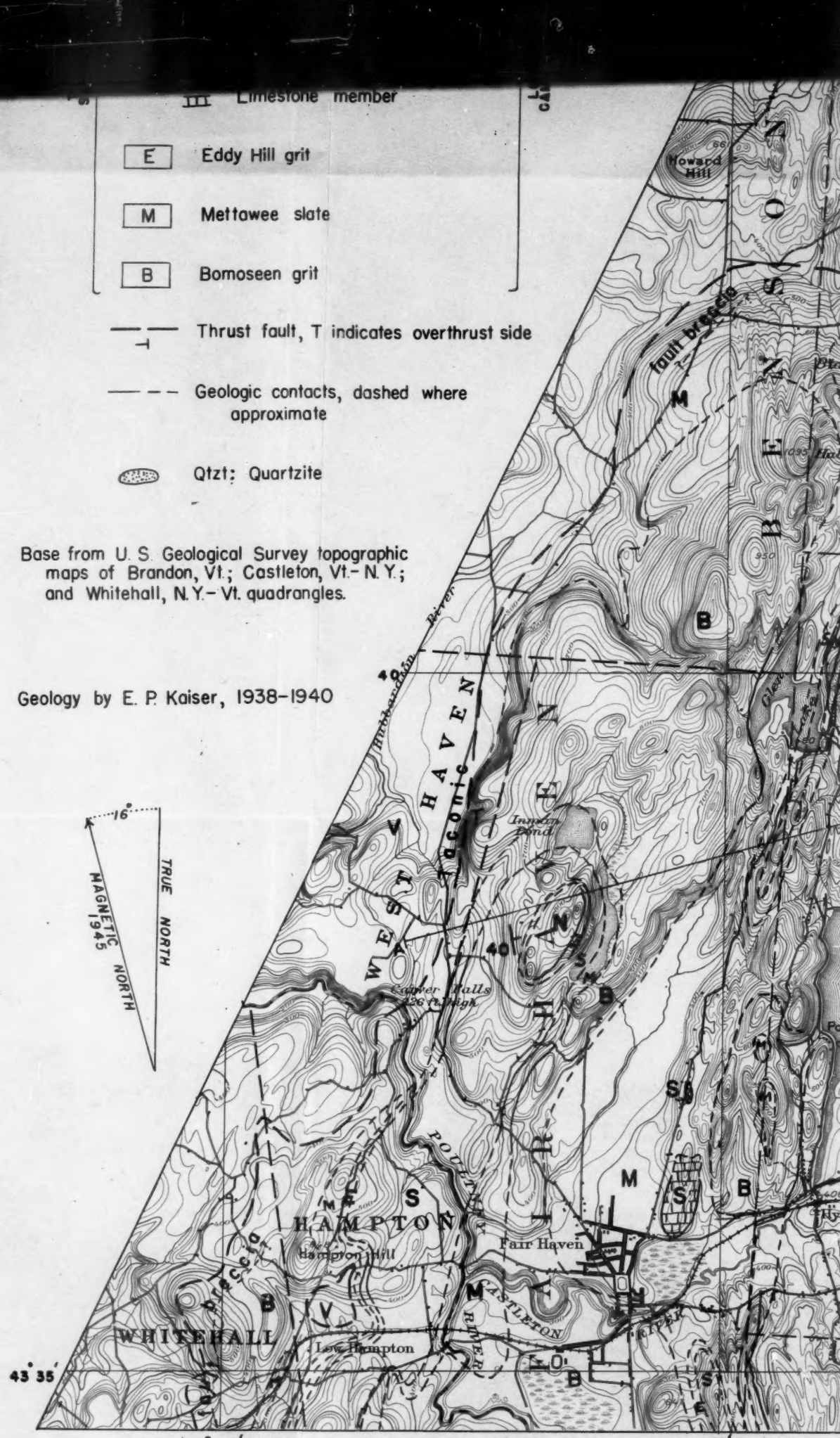
Base from U. S. Geological Survey topographic maps of Brandon, Vt.; Castleton, Vt.- N. Y.; and Whitehall, N. Y.- Vt. quadrangles.

Geology by E. P. Kaiser, 1938–1940

16°

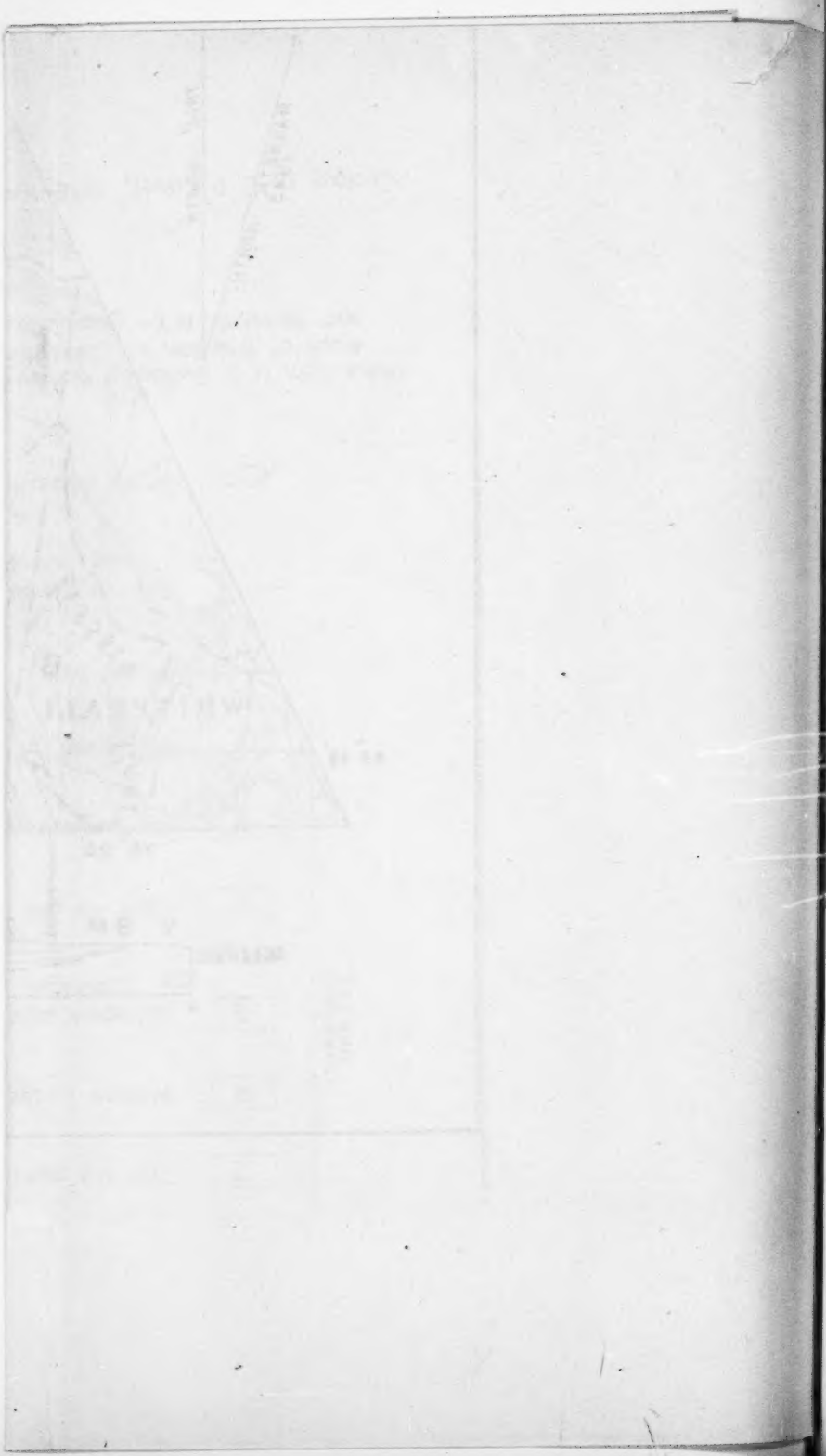
MAGNETIC 1945 NORTH

TRUE NORTH


Howard Hill
fault breccia
Rutland
Rutland Junction
Rutland Junction
Rutland Junction

BC; horizontal and vertical scales equal

THE NORTHERN TACONIC AREA



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SEDIMENTS OF TROUT LAKE, WISCONSIN

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CONTENTS

	Page
Abstract	1099
Introduction	1100
Sources of sediments entering Trout Lake	1102
Shore and offshore deposits of Trout Lake	1103
Shore and offshore deposits of the islands	1106
Bottom deposits of Trout Lake	1108
Sampling along ranges	1108
Description of some Trout Lake sands	1116
Sands of Trout Lake	1121
Spud sampling	1122
Fine-grained sediments of Trout Lake	1127
Megascopic appearance of gyttja from Trout Lake	1127
Mechanical analyses of gyttja	1128
Core samples	1132
Iron and manganese sediments in Trout Lake	1138
Stratification of sediments in Trout Lake	1141
Rate of deposition and diagenesis of the gyttja	1142
References cited	1142

ILLUSTRATIONS

Plate	Facing page
1.—Map of Trout Lake showing shore sectors and stations of sampling	1100
2.—Iron and manganese deposits	1140
3.—Map of Trout Lake showing distribution of iron and manganese deposits	1142

ABSTRACT

Sediments were collected with Eckman and Petersen dredges from the bottom of Trout Lake, northern Wisconsin, at 221 stations. Sampling was done with a spud sampler at 32 stations, and core samples were obtained with a Jenkins and Mortimer and a Twenhofel sampler at 17 stations.

The shore and offshore deposits of the shores of Trout Lake and the shores of the islands are described. Megascopic descriptions are given of the samples collected with the Eckman and Petersen dredges. Sediments on bottoms of about 10 meters or deeper are mainly gyttja, or crusts composed of mixtures of organic matter, ferric hydroxide, and some form of manganese oxide. The latter deposits are extensive. Detailed descriptions of some of the samples of sands are given, and generalizations respecting size and distribution are made. Tables showing quartiles, medians, and coefficients of sorting and skewness of the coarse sediments collected from the bottom are given in tables. Mechanical analyses of all fine sediments, mainly gyttja, were not made, as previous experience seems to have demonstrated that results have no sedimentational value. Organic matter of the gyttja was determined and also the percentages of lignin in the organic matter.

Core samples are composed almost entirely of fine materials, mainly gyttja, and determinations were made on these samples in the same way as on the samples obtained with the Eckman and Petersen dredges. Studies of the core samples show that the fine sediments usually contain in excess of 90 per cent moisture and there is very little change in the moisture content from top to bottom of cores.

A map shows the distribution of the iron and manganese deposits. These deposits were found to contain 10 to 20 per cent of organic matter, 11 to 16 per cent of metallic iron, and 12 to 30 per cent of metallic manganese.

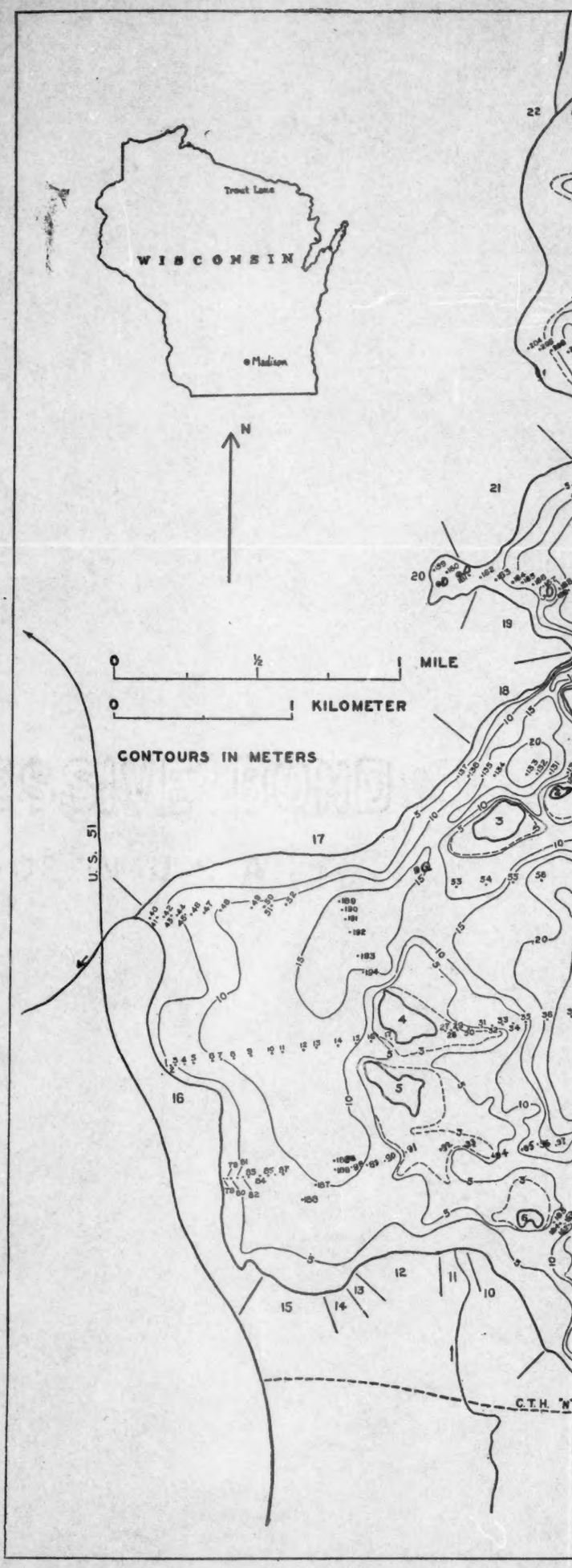
No stratification of any kind was found in any of the deep-water sediments of Trout Lake except in the iron and manganese crusts. Absence of stratification is considered to be due to the slow rate of deposition and the mixing of sediments by organisms which dwell in them. The data indicate that the rate of deposition in the deep waters of Trout Lake is of the order of 1 foot in 15,000 years.

INTRODUCTION

Trout Lake (Pl. 1) is situated in the Northern Highlands State Forest of Wisconsin in what is known as the Northern Highlands Lake District. It is the largest lake in the district as well as one of the deepest. The organic and inorganic features of Trout Lake have been studied for many years by the Wisconsin Biological and Natural History Survey whose laboratory is situated on the east shore of the southern part of the lake. Studies of the lake and its waters have been made in this laboratory under the supervision of Doctors E. A. Birge and Chancey Juday. These studies are well known to all students of limnology.

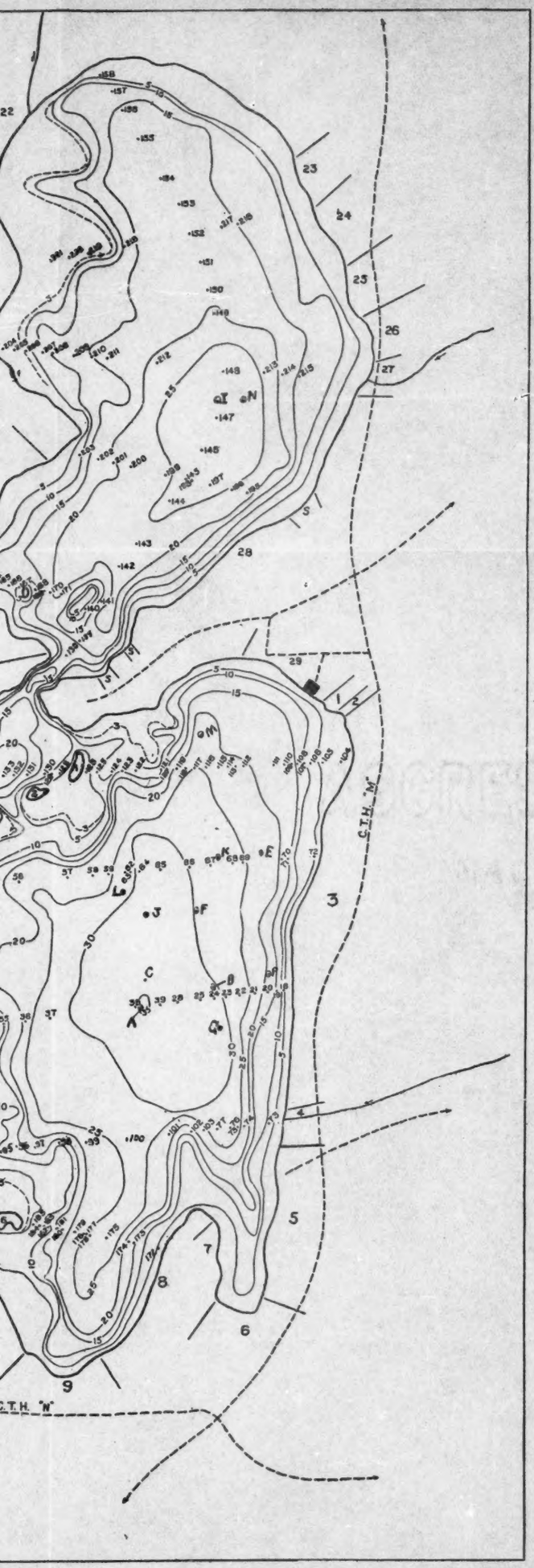
Trout Lake consists of two lakes connected by a narrow passage known as the Narrows. The northern part is designated North Trout Lake, and the southern part South Trout Lake. The latter is the larger, has about the same length in the north-south direction as North Trout Lake, but is about twice as wide. The combined length of the two lakes is about 7 kilometers, or 4.5 miles. The greatest width of South Trout Lake is about 4 kilometers or 2.4 miles. The total area of the lake is 6.1 square miles of which about 2 square miles is in North Trout Lake and about 4 square miles in South Trout. South Trout Lake is the deeper, and the deepest part (35 meters or 114 feet) is about one fourth the distance from the middle of the east shore to the middle of the west shore. The maximum depth of North Trout Lake is 25 meters, or about 82 feet. The total volume of water in the lake has been estimated to be in excess of 200,000,000 cubic meters. The shore line has a length of 25.5 kilometers, or 16 miles.

North Trout Lake has one small island just north and a little west of the Narrows. There are six islands in South Trout Lake which are arranged in a somewhat northeast-southwest direction across the middle. These islands seem to be a continuation of the long eastern peninsula which divides the lake into two parts. This chain of islands and the adjacent shallow water divides South Trout Lake into two parts of which the eastern part has a maximum depth of 35 meters and the western of 15 meters. It should be noticed that the western basin is shallower. It is obvious that the islands in the lake were once larger than now, as they are now being eroded at the shores and each storm produces some encroachment of water. Each island is surrounded by areas of shallow water on bottoms covered with gravel and sands,



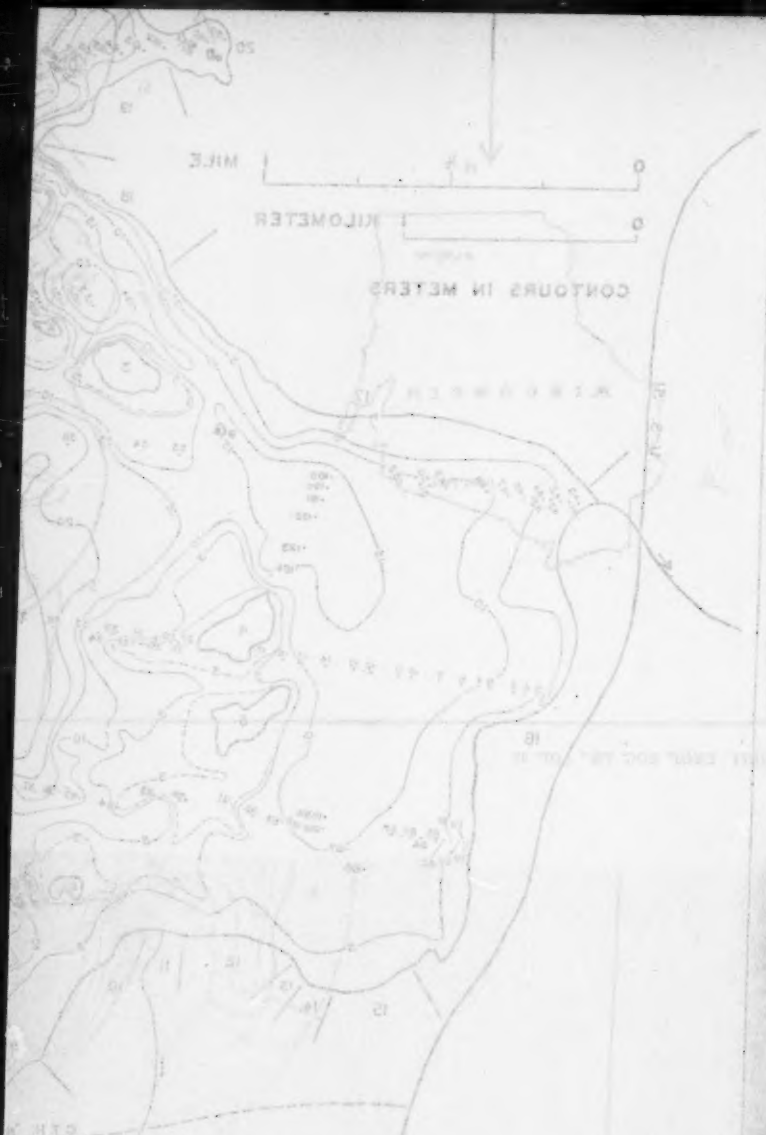
MAP OF TROUT LAKE SHOWING SHORE SEC

Stations sampled with Eckman or Petersen dredges shown by numbers; st
numbers in line traverses.



E SECTORS AND STATIONS OF SAMPLING

bers; stations of core samples indicated by letters. Ranges indicated by



and some parts of these areas may be considered to represent the extent of the islands eroded. It must not be concluded, however, that the total area of shallow bottom around each island represents area which was once island. Parts of the shallow bottoms represent fill made by materials eroded from shores. The original islands were probably formed as crevasse fillings in stagnant ice to which the lake is due. Gravel-covered bars in South Trout Lake may represent islands which have been completely eroded.

The shores of the lake are largely covered with timber and doubtless were entirely covered until comparatively recent time. Most of the present timber is second growth. Shores which are being prograded are low. Places of erosion are steep, but the maximum height of cliffs probably does not exceed 8 meters or about 25 feet. Small cliffs and steep banks seem to be more abundant than other forms of shore line.

Ice shove is strong on Trout Lake and, where conditions permit, a low ridge lies above the beach. This process evidently is important in preparing the materials of the shores for erosion by waves.

Four small streams flow into Trout Lake. One enters North Trout about the middle of the east shore, and there is another on the northwest corner. A stream draining Lake Allequash flows into South Trout south of the middle of the east shore, and another stream enters about the middle of the south side. There is evidently considerable flow into the lake by seepage from the outwash sands which surround it. The outlet is about the middle of the west side of South Trout Lake.

Trout Lake lies in a depression in glacial outwash. Surrounding materials are mainly outwash sands (Thwaites, 1929) and thin till, the latter present over the outwash on the southeast side of the lake (Fries, 1938). Locally, the outwash contains considerable gravel.

Study of the sediments of Trout Lake was made possible through the financial support of the Graduate School of the University of Wisconsin. Most of the dredging was done by Mr. McKelvey during the summers of 1939 and 1940. Some was done by Mr. Nelson during the summer of 1941, and additional dredging was done by Mr. Feray in the summer of 1942. Mr. Feray mapped a part of the distribution of the iron deposits in the summer of 1942. Other areas remain to be mapped.

Professor Philip Carpenter of Iowa State College assisted Mr. Nelson and Mr. McKelvey in the dredging, and he obtained samples for bacteriological studies. Personnel of the Trout Lake Biological Laboratory assisted Mr. Nelson in obtaining core samples. The work was carried on with the cordial and generous co-operation of the staff of the biological laboratory and particularly with the generous co-operation of Doctors Chancey Juday and L. E. Noland.

Sampling was done with Ekman and Petersen dredges at 221 stations on 13 ranges, the former used for fine-grained sediments, the latter where the sediments were of sand or larger dimension. Sampling was done with a spud sampler at 32 stations, and attempts were made to obtain core samples at 17 stations. A core sampler devised by the senior writer was used at some stations, and at others the Jenkins and Mortimer core sampler was used.

SOURCES OF THE SEDIMENTS ENTERING TROUT LAKE

The sediments entering Trout Lake are derived from erosion of the shores and from the atmosphere; some are brought to the lake by streams, some fall into the lake from margining vegetation, and plants and animals dwelling in the lake are responsible for some.

In a large lake, such as Trout Lake, wave action is strong, and erosion of the shores produces a considerable volume of sediments. The shore is largely, if not entirely, composed of sediments deposited by the melt water of a glacier. Sands are extremely abundant, in some places to the extent of almost total exclusion of other materials. Thus, erosion of the shore and acquirement of sediments are comparatively easy. Large particles in the range from granules to boulders are locally present. There is little sediment of clay and silt dimensions. As the shores are eroded, most large particles remain with the beach or on the shallow bottoms produced by the erosion. Some sands stay on the beach and the adjacent shallow bottoms, more move into the bays where the shore is being prograded, and some are undoubtedly transported to bottoms below the base level of erosion. This is done by currents due to turbidity gradients, by undertow, and probably by some form of rip current. An important method of movements of sand from the shores of Trout Lake is by floating on the surface (McKelvey, 1941). This at times is very great, and the quantities moved under favorable conditions represent transportation of the first order of importance. A considerable volume of sands may be blown away from the shores in winter when the lake is covered with ice and the ice is free from snow. The quantity thus moved from the shores to places on the ice over deep bottoms is not known, but it may be large. Particles of clay and silt dimension have left most of the beaches and have been deposited over the deeper bottoms of the lake. The extents of shallow bottom around the islands, over gravel bars which once may have been islands, and about the parts of the shores which are being actively eroded indicate to some degree the quantities of sediments deposited over the bottom of the lake by erosion of the shores.

Considerable quantities of organic and inorganic sediments are doubtlessly brought to the lake by way of the atmosphere. Inorganic materials contributed by the atmosphere are derived from roads, the cultivated fields of the region, and from the dry areas of the Prairie and Plains region of the United States and Canada (Winchell and Miller, 1918; 1922). Sediments derived from this sources may be quite large at times. Large quantities of organic matter are also brought to the lake by the wind. These are largely derived from the margining vegetation and consist of pollen grains, spores, spore cases, leaves, and twigs.

The four small streams entering Trout Lake bring some organic and inorganic sediments in suspension, but most of the sediments thus introduced are thought to be in solution or in colloidal form. Silica, compounds of iron and manganese, a little calcium and magnesium, and doubtless other substances are thus introduced. That iron, manganese, and silica are introduced is shown by the iron and manganese deposits over parts of the bottom of the lake and by the tests of diatoms which dwell in the lake. The streams, or seepage, carry very little calcium or magnesium car-

bonates, so the waters are soft, and shell life is not common. The methods of entrance of iron and manganese are not known, but both probably enter as carbonates and as colloids. Very fine organic sediments are brought by the streams as is shown by the brown color of the water. This water comes from swamps, and the organic matter is either in solution or suspension.

Considerable volumes of sediments are produced in the lake. Diatoms precipitate silica in the form of tests, and many species make the lake their home. Various organisms produce shells although a large number is not apparent. Many parts of the bottom support a plant growth, and numerous planktonic and other algae and various higher plants live in the waters. The waters also support numerous small forms of animal life which construct tests of chitin, and seasonally many animals pass their larval stages in the waters.

The sediments in Trout Lake are divided into two classes: (1) shore and offshore deposits, and (2) deep-water deposits.

SHORE AND OFFSHORE DEPOSITS OF TROUT LAKE

The shore and offshore deposits were studied by Mr. Nelson from a boat and by walking along the shores. The islands in South Trout Lake have been numbered 1 to 6. The small island in North Trout Lake is not numbered. The shore of the lake has been divided into 29 sectors as shown on the map (Pl. 1). Descriptions of the sediments of each sector and the character of the shore in each are given in the paragraphs which follow.

1. This sector begins about 150 meters east of the last buildings of the biological laboratory. The beach is about 6 meters wide, and the sediments consist of large pebbles and cobbles. Similar sediments extend into the shallow water for about 6 meters and then pass into sands.

2. The beach is narrow, and the sediments consist of large cobbles and boulders. Similar sediments extend into shallow water for about 5 meters and then abruptly pass into sands. The sector covers the bend of the shore where the direction changes from east-west to north-south.

3. This sector includes the north end of the north-south shore and extends almost to the mouth of the creek draining Lake Allequash. The beach ranges in width from 2 to 3 meters. The beach sediments consist dominantly of large pebbles and small cobbles and thence outward for about 50 meters the bottom is covered with sediments in the range from sands to boulders. No dimension of particles seems to have dominance. Patches of sands without larger particles are intermittently present.

4. This sector, a narrow one about the mouth of the creek draining Lake Allequash, extends from about 4 meters north of the creek to about 16 meters south. The shore and shallow-water sediments consist dominantly of granules and small pebbles.

5. Sector 5 extends from about 16 meters south of the creek draining Lake Allequash to the east side of the head of the small bay on the southeast corner of South Trout Lake. The beach sediments consist of particles in the range from pebbles to boulders, and similar sediments extend outward from the shore for 3 to 6 meters and then abruptly pass into sands.

6. Sector 6 forms the head of the small bay on the southeast corner of South Trout Lake. The beach and shallow-water sediments consist of sands.

7. Sector 7, on the east side of the peninsula separating the small bay on the southeast corner of South Trout Lake from the main body of the lake to the west, has no beach, and vegetation extends to the water. The shallow-water sediments consist of sands.

8. Sector 8 includes the end and the west side of the peninsula separating the small bay on the southeast corner of South Trout Lake from the main body of the lake to the west. The beach sediments are in the range from pebbles to boulders with the coarsest sediments about the end of the peninsula. The shallow-water sediments are like those of the beach and extend outward for about 50 meters on the end of the peninsula and for about 16 meters on the west side with the dimensions gradually decreasing to sand size with depth and distance from the shore. The beach is narrow and in the range from 1 to 3 meters. There is a local concentration of large pebbles, cobbles, and boulders extending to the southeast from the head of the peninsula which resembles a spit, but may be of artificial origin.

9. Sector 9 covers the head of the wide bay which forms the south end of South Trout Lake. The sediments of the beach about the head of the bay consist largely of sands with some granules and small pebbles. These sands pass westward to granules and small pebbles and finally to large pebbles and cobbles. The offshore deposits consist largely of sands except for a narrow strip about 1 meter wide about the head of the bay. This strip consists of granules and pebbles which are coarser than the granules and pebbles of the adjacent beach. The sediments of this narrow strip pass abruptly outward into sands.

10. Sector 10 extends from the west side of the bay of sector 9 to the end of the wide point on the west. The beach and offshore sediments consist of sands, granules, pebbles, and cobbles. They pass into sands at distances from the shore ranging from nothing to 10 meters.

11. Sector 11 covers a narrow strip about 50 meters wide about the mouth of the small creek on the south side of Trout Lake. The sediments of the beach are sands and granules. Offshore deposits are sands with some pebbles.

12. The beach and offshore deposits of sector 12 are composed of cobbles and boulders. These pass into sands and small pebbles about 30 meters outward from the shore.

13. Sector 13, about 50 meters long, is on the east side of the broad bay on the southwest corner of Trout Lake. The beach and offshore deposits consist of sands. The offshore sands are separated from those of the beach by a band of pebbles at the shore. This band has a width of about a meter.

14. Sector 13 passes into 14 with the beach sediments changing from sands to large pebbles, cobbles, and boulders. Most particles are iron-stained. This variety of sediments extends for about 2 meters from the shore and abruptly passes into sands, pebbles, and small cobbles.

15. Sector 15 covers a bay head beach. The beach is about 4 meters wide, and both beach and offshore deposits consist of sands.

16. Sector 16 extends from the west side of the head of the bay of sector 15 to and

including the entrance to the outlet of Trout Lake. The beach deposits are largely pebbles and cobbles with patches of sands at two places. The offshore deposits are largely sands with minor quantities of pebbles and cobbles. On the south side of the outlet for about 6 meters the deposits of the beach are granules and pebbles. The bed of the outlet is composed of particles in the range from pebbles to cobbles. Offshore deposits about the entrance of the outlet are sands, granules, pebbles, and cobbles. These extend outward for about 6 meters and then pass abruptly into sands.

17. The sediments of the beach and offshore for about a quarter of a mile northeastwardly from the beginning of sector 17 are sands with a band of granules and small pebbles at the shore. This band has a width of about one meter. These sediments pass northwestwardly into pebbles and cobbles which extend to the end of the sector. The offshore deposits on this part of the sector consist largely of sands with minor quantities of pebbles and cobbles. Offshore sediments are coated with iron oxide.

18. This sector of the shore consists of a succession of small inlets and points. It extends to the beginning of the Narrows separating North Trout Lake from South Trout Lake. Beach and offshore deposits of the bays consist largely of sands. Sediments of the points are largely composed of cobbles with the offshore deposits largely sands with minor quantities of granules, pebbles, and cobbles.

19. This sector extends from the Narrows to the south side of the small bay on the north side of the Narrows. The beach sediments of this section of the shore and the shore of the adjacent small island consists of pebbles, cobbles, and boulders. Sediments of similar character extend outward for 3 to 16 meters and then pass into sands. The point at the Narrows has beach sediments of sands, granules, and small pebbles. The sediments of the beach are iron-stained for about 100 meters on the west end of the sector.

20. This sector of the shore has no beach and vegetation extends to the water. Offshore sediments are muds.

21. Sector 21 has a beach covered with pebbles, cobbles, and boulders except for a short stretch of sand in an indentation. Offshore sediments are similar for about 20 meters from the shore except that sands are common.

22. This sector extends around the north end of the lake. Beach sediments are sands which gradually pass into the sediments of sectors 21 and 23. Offshore deposits are sands.

23. The beach sediments consist of pebbles and cobbles. This form of sediment extends outward for about 2 meters from the shore and then abruptly passes into sands.

24. This sector of the shore, about a quarter of a mile long, is covered with sands, granules, and pebbles. Offshore deposits are largely sands with a few granules and pebbles.

25. This sector, about a quarter of a mile long, has the beach composed of pebbles, cobbles, and boulders. Offshore sediments are sands, granules, pebbles, and cobbles with a few boulders. These offshore deposits extend outward for about 30 meters from the shore and then pass into sands.

26. Sector 26 is a bay head just north of the creek entering North Trout Lake from

the east. Beach and offshore sediments are composed of sands which are separated at the shore by a strip about a meter wide of which the sediments consist of granules and small pebbles.

27. This sector, on both sides of the small creek entering North Trout Lake from the east, has the beach and offshore sediments composed of sands, granules, pebbles, and cobbles. The sediments are iron-stained for about 130 meters south of the creek and for about 16 meters north.

28. Sector 28 includes the peninsula separating North Trout Lake from South Trout Lake. The sediments of the beach are mostly pebbles, cobbles, and boulders. These have been washed from the shore which has receded before attack by waves. The shore is steep and is subject to active erosion. Offshore deposits are like those of the shore for from 3 to 16 meters outward where they change to sands. Separation ranges from sharp to gradational. Three small bays, indicated by *S* on the map, have beach and offshore deposits composed of sands.

29. This sector extends from the Statehouse pier to the beginning of Sector 1. The beach is about 10 meters wide, is one of the widest on the lake, and the beach and offshore sediments consist of sands.

SHORE AND OFFSHORE DEPOSITS OF THE ISLANDS

The islands are considered to represent remnants of larger islands, and several shallow bars are probably the last remnants of former islands. These bars are covered with pebbles, cobbles, and boulders which the waves could not remove. The offshore deposits of the islands contain many cobbles and boulders which were left in or near their present positions because the waves could not remove them.

ISLAND NO. 1: The sediments of the beach on the east side of this island consist of pebbles, cobbles, and boulders. Offshore sediments are similar except that they contain considerable sand. These sediments extend outward for approximately 16 meters on the northeast side of the east shore. This outward extent increases to the south until at the south end of the east shore the coarse sediments extend for 300 to 375 meters outward from the shore. The beach sediments of the west side of the island average generally smaller than those of the east side and consist of sands, granules, pebbles, and cobbles. Offshore sediments are similar and extend outward for only about 6 meters where they pass into sands. A bar composed of sands, granules, pebbles, and cobbles connects Island No. 1 with Island No. 2. The extents and characters of the beach and offshore sediments on the two sides of the island are probably due to greater erosion on the east side than on the west side as the east side faces a greater extent of water.

ISLAND NO. 2: The sediments of the beach on the south side of the island consist of pebbles, cobbles, and boulders. Offshore sediments consist of particles in the range from sands to boulders. These extend outward for approximately 200 meters from the shore and gradually pass into sands. The beach and offshore sediments on the north side of the island consist of sands, granules, and pebbles. These gradually pass into sands about 6 meters from the shore. Concentrations of large particles on the south side of Island No. 2, as on the east side of Island No. 1, are probably due to

greater erosion on this side as it faces the larger extent of water. The differences may also be due to greater abundance of large particles in the materials eroded. Islands Nos. 1 and 2 may be remnants of a one-time single large island.

ISLAND NO. 3: The sediments of the beach on the northeast side of Island No. 3 consist of granules and small pebbles. Offshore deposits are similar except that the pebbles are larger, and there is more sand. The sediments of the shore on the eastern tip of the island are pebbles and cobbles. This form of sediment extends into the shallow water for about 2 meters from the shore and then passes abruptly into sands. The sediments of the beach on the south and west sides consist of large pebbles, cobbles, and boulders. Offshore sediments are similar but contain more sand. These extend outward for about 200 meters from the shore and then pass into sands. The northeast side of this island seems to have suffered the least erosion.

ISLAND NO. 4: The sediments of the entire beach of Island No. 4 consist of pebbles and small cobbles except on the south side where a small spit is composed of sands, granules, pebbles, and cobbles. All sediments gradually pass into sands a short distance from the shore except on the southeast side where the coarse sediments abruptly pass into sands about 2 meters from the shore.

ISLAND NO. 5: The sediments of the entire beach of Island No. 5 consist of pebbles and cobbles except in the bay on the north side and the point and bay on the south side, where the sediments are sands, granules, and small pebbles. Offshore sediments, except in the two bays noted, consist of sands, granules, pebbles, and cobbles. The shore sediments without much change extend into the shallow water for distances ranging from about 2 meters around most of the island to as great as about 200 meters at places on the north side.

SUMMARY OF SHORE DEPOSITS: The descriptions of the shore and shallow water deposits show that the sediments vary greatly from place to place on the shore and in distances outward from the shore. These sediments are largely derived from the outwash materials of which the surrounding lands are composed. These materials vary in dimension from place to place, and this variation accounts for some of the size differences of the shore and offshore sediments. A second cause of variation is the strength of the wave and current attack on the shore. Shores are eroded where waves and currents are strong, fine particles are removed, and the beach deposits consist of those particles which are too large for the waves and currents to move. In places where there is little to no wave and current attack and sediments are not brought, plants invade the water. Such is the case in the two sectors of 7 and 20 where the vegetation invades the water. Sands are brought to some parts of the shore to make beach and offshore deposits, but many parts of the shore have such composition because the bank materials are composed of sands. As the bank materials at most places contain little clay or silt, these forms of sediments are largely wanting in the shore and offshore sediments.

McKelvey (1940) showed that the beach deposits of Trout Lake have textural zones paralleling the water's edge and that each zone has distinctive features. He distinguished eight zones. McKelvey's work shows that collection of samples on the beach of Trout Lake requires attention to the phase of beach environment in which the sediments were deposited. The senior writer has found this to be the case on sea beaches.

Extent of coarse sediments outward from the shore is variable. In some places coarse sediments extend only a meter or so outward; in other places such sediments may extend outward for a third of a kilometer. Distance from shore seems to be conditioned by depth of water. If the bottom adjacent to a shore is below the base level of erosion, the coarse sediments extend only a short distance outward. If the bottom is above this level for any considerable distance outward, the outward extent of coarse sediments is also considerable.

It was noted in several sectors, where both beach and offshore sediments are sands, that a band of granules and pebbles about a meter wide is immediately adjacent to the shore or only a short distance outward. This band is situated where the waves break, and its presence is due to the competency produced by turbulence. This competency removes the fine sediments and leaves the coarse. It is assumed that the position of this band varies with the dimensions of the waves and thus is at different places at different times. If the conditions were those of a rising lake level, initial sediments in some places might be sands, and these might be succeeded by a zone containing many pebbles and granules, and this zone would be succeeded by sands, as the granule and pebble band would migrate shoreward as the waters rose.

The rapidity of change in the beach and offshore sediments from coarse to fine seems important. In places this change takes place in less than a meter, in others the change may extend over more than 100 meters.

BOTTOM DEPOSITS OF TROUT LAKE

SAMPLING ALONG RANGES

Bottom sampling was carried on along lines designated ranges. These were selected with the plan to cover the floor of the lake as completely as possible so as to yield a fairly accurate picture of the bottom sediments. Eckman and Petersen dredges were used, the former where the sediments were thought to be of silt and clay dimension, the latter where they were thought to be of sand or larger dimension. Errors of judgment were not infrequent. Distances between sampling stations were short where the sediments were expected to change over short distances, long where essential constancy of sediments was expectable. Gross descriptions of the sediments as they were taken from the dredges are given in the tables which follow.

Dredging in a lake as large as Trout Lake is not always easy or possible. Little may be done when there is much wind, as position cannot be maintained, and it is difficult to keep on the line of a range. Location of stations was determined by triangulation and by reference to geographic positions. Distances were checked with a range finder.

RANGE 1

Range 1 extends from about the middle of the west side of South Trout Lake to about the middle of the east side and passes through Island No. 4. The traverse was begun on the west end of the range and carried to the island and was continued beginning on the east shore and carried to the island.

Station	*Distance from shore* (Meters from W shore)	*Depth of water* (Meters)	*Sediments*
1	15	1	Sand
2	30	2	Sand
3	45	6	Sands
4	108	6	Fine gray sand
5	150	8	Gyttja
6	250	8.5	Gray sand
7	280	9	Gray sand
8	360	9	Gray-green gyttja
9	450	9.5	Gray sand
10	585	10	Gyttja
	(Meters W. of W. shore of Island No. 4)		
11	630	11	Gyttja
12	500	6	Sand and gravel
13	430	13	Gyttja
14	300	8	Sand and gravel
15	220	4	Sand and gravel
16	125	2	Gray sand
17	10	2	Sand, gravel, boulders covered with algae
	(Meters from E. shore)		
18	60	2.3	Sand and gravel, clam in sample
19	85	9	Sand and gravel
20	120	13.3	Grayish-brown sand and fine gravel
21	165	19.5	Fine gray sand and mud
22	220	27	Gray gyttja
23	270	29	Gray gyttja
24	340	32.5	Gray gyttja
25	400	33	Gray and black gyttja
26	495	34	Dark gray gyttja
	(Meters E. of Island No. 4)		
27	28	.3	Dirty sand and gravel
28	54	.7	Rippled sand with some weeds
29	70	1.3	Sand and very fine gravel
30	150	1.2	Sand and gravel
31	225	1.5	Sand and gravel
32	270	8	Sand and gravel
33	315	13.8	Fine sand with some mud
34	380	13.5	Very fine sand, some mud
35	450	19	Very fine sand and mud
36	585	29	Gray gyttja
37	720	30	Gray gyttja
	(Meters W. from E. shore)		
38	720	34.5	Greenish-black gyttja, one twig
39	490	34	Greenish-black gyttja

RANGE 2

Range 2 begins at the outlet of Trout Lake and extends east to the Biological Laboratory on the east shore. The outlet has an approximate width of 9 meters, and the water is .4 to .6 meter deep. Good flow of water was present in August 19[illegible] when the traverse was made, and the bottom of the channel was covered with coarse cobbles with sands on the margins.

Station	*Distance from shore* (Meters E. of W. shore)	*Depth of water* (Meters)	*Sediments*
40	58	2.5	Fine gray sandy mud with many weeds
41	95	2	Fine sand
42	125	1	Sand and gravel (cobbles), one clam
43	180	2	Fine sand
44	215	4.5	Gray sludge, many weeds
45	250	4	Fine gray sand and silt, many weeds
46	300	2	Brown sand and pebbles
47	360	8	Gray muddy sand
48	450	10	Gray gyttja
49	630	10	Gray sand and pebbles
50	680	14	Sand and pebbles
51	720	16	Gyttja
52	810	12	Sand and gravel
53	Half way between points of islands 3 and 4	14	Gray sand, brown on top
54	Half way between middle of islands 3 and 4	8	Sand
55	Half way between E, points of islands 3 and 4	15	Sand
56	*See* map	14	Pebbles coated with iron oxide, iron-oxide concretions, and iron-coated sand
57	*See* map	24.5	Gyttja
58	*See* map	24.8	Gyttja
59	*See* map	23	Gyttja
	(Meters W. of E. shore)		
60	90	4.5	Sand
61	110	11	Red sand
62	*See* map	24	Gray gyttja
63	*See* map	22	Iron-oxide concretions and gray sandy sludge
64	*See* map	32	Gray gyttja
65	*See* map	32.5	Gray gyttja
66	*See* map	28	Gray gyttja
67	*See* map	28	Gray mud

Station	*Distance from shore* (Meters W. of E. shore)	*Depth of water* (Meters)	*Sediments*
68	270	28	Gray mud
69	215	27.5	Gray mud
70	180	19	Black mud
71	135	17	Sand
72	45	4	Coarse gravel

RANGE 3

Range 3 begins at the outlet from Allaquash Lake and, with interruptions in the island region, extends to the west side of the lake. The inlet is floored with pebbles, cobbles, and boulders at the shore but has sands above the shore. It is about 5 meters wide and .4 to .6 meters deep.

Station	*Distance from shore* (Meters W. of E shore)	*Depth of water* (Meters)	*Sediments*
73	108	7.5	Gray sand
74	140	20.5	Sand and pebbles coated with iron oxide and iron-oxide concretions
75	160	24	Gray mud
76	225	28	Gray mud
77	260	27	Greenish brown sludge
	(Meters E. of W. shore)		
78	16	1	Sand, brown on surface, gray beneath
79	43	2.5	Cobbles, iron-stained
80	58	3.5	Gray sludge with pond weeds
81	90	3.5	Gray sludge with pond weeds
82	120	1.5	Iron stained gravel
83	145	2	Gray sand, brown on top, many weeds
84	216	1.5	Sand and gravel
85	250	7.5	Iron coated gravel
86	300	9.5	Iron concretions
87	325	13	Gyttja
88	*See* map	10.5	Gray gyttja with iron concretions
89	*See* map	13.5	Gray gyttja
90	*See* map	7	Fine gray sand, iron-stained on top
91	*See* map	1	Brown sand and gravel
92	*See* map	1.5	Gray sand, brown on surface
93	*See* map	6.8	Gray sand with a few pebbles, iron-stained on surface
94	*See* map	4.5	Gray sandy mud, full of weeds
95	*See* map	4.5	Gray sandy mud, full of weeds
96	*See* map	7	Fine gray sand, few pebbles, reddish-brown on top
97	*See* map	2.5	Brownish-gray sand, a few weeds, no mud
98	*See* map	8	Brownish-gray sand
99	*See* map	2	Fine gray sand, a little mud

Station	Distance from shore (Meters E. of W. shore)	Depth of water (Meters)	Sediments
100	*See* map	24	Fine gray sand, a little mud
101	*See* map	24	Greenish-gray gyttja
102	*See* map	23	Greenish-gray gyttja
103	*See* map	23	Gray sand, some iron coated and iron concretions. The sands rest on pinkish clay.

RANGE 4

Range 4 extends directly across the north end of South Trout Lake from the east to the west shore.

Station	Distance from shore (Meters from E. shore)	Depth of water (Meters)	Sediments
104	36	1.3	Sand with a few weeds
105	58	4.5	Grayish-brown sand
106	95	7.3	Reddish-brown sand
107	120	8.3	Reddish-brown sand with a little mud
108	150	10	Iron-coated pebbles and iron-oxide concretions
109	165	15	Iron-coated sand and pebbles
110	205	16.7	Gray gyttja
111	235	17.5	Gray gyttja
112	305	22.3	Gray gyttja
113	360	22.5	Gray gyttja
114	450	22.5	Gray gyttja with black streaks
115	540	22.3	Gray gyttja
116	*See* map (Meters E. of point of Island No. 1)	25	Gray gyttja
117	540	28	Gray gyttja
118	450	27	Greenish-gray gyttja
119	400	24	Greenish-gray gyttja
120	360	15	Gray sand, red on top
121	315	14	Concretions of iron oxide, iron-oxide-coated sand and pebbles
122	270	6	Gray sand, red on top
123	210	5	Gray sand, gravel and weeds
124	150	2.3	Sand and gravel
125	80	8.3	Muddy gray sand
126	10 (Meters W. of Island)	5	Gray sand
127	32	6	Gray sand
128	72	10	Gray sand, brown on top
129	117	9.3	Gray sand, brown on top, overlying red clay
130	180	15	Brown sand
131	215	17.3	Yellow brown gyttja
132	270	21	Greenish-gray gyttja
133	340	20	Greenish-gray gyttja

Station	Distance from shore (Meters E. of W. shore)	Depth of water (Meters)	Sediments
134	250	12	Yellowish-brown gyttja
135	160	16	Yellowish-brown gyttja
136	85	9	Gray sand
137	34	2	Sand, gravel, boulders, more or less iron-stained

RANGE 5

Range 5 extends from the Narrows to the north end of North Trout Lake.

Station	Distance from shore (Meters)	Depth of water (Meters)	Sediments
138	*See* map	9	Hard bottom with light-brown sand and gravel
139	*See* map	17	Gray sand and gravel, brown on top, a few sticks, bark, and pine cones
140	*See* map	10	Pebble bottom, pebbles covered with algae and iron-stained
141	*See* map	16.8	Gray sand and pebbles, brown on top
142	*See* map	24.5	Gray gyttja
143	*See* map	24	Hard bottom, probably iron oxide crust
144	*See* map	26.8	Gray gyttja with top stained red
145	*See* map	27	Gray gyttja
146	*See* map	27.5	Black gyttja
147	*See* map	28.5	Black gyttja
148	*See* map	28.5	Black gyttja with top stained red
149	*See* map	20	Greenish-gray gyttja
150	*See* map	19.5	Greenish-gray gyttja
151	*See* map	17	Greenish-gray gyttja
152	*See* map	16	Greenish-gray gyttja, contained a pine cone
153	*See* map	16.5	Greenish-gray gyttja
154	*See* map	18	Greenish-gray gyttja
155	*See* map	15.5	Greenish-gray gyttja
156	*See* map	14	Greenish-gray gyttja
157	*See* map	14.5	Greenish-gray gyttja
	(Meters from shore)		
157a	45	12	Greenish-gray gyttja
158	30	10.5	Greenish-gray gyttja with sand and fragments of wood

RANGE 6

Range 6 extends across the south end of North Trout Lake. It begins at the spring hole on the west shore. This hole has a sand-gravel bottom covered with a thin layer of sand. There is no indication of wave erosion at the shore.

Station	Distance from shore	Depth of water (Meters)	Sediments
159	*See* map	1	Light-brown gyttja
160	*See* map	0.5	Light-brown gyttja
161	*See* map	0.8	Light-brown gyttja
162	*See* map	0.5	Gravel-cobble bottom, covered with algae

Station	Distance from shore	Depth of water (Meters)	Sediments
163	See map	2.8	Gray sludge and weeds
164	See map	8	Sand and cobbles, red on top
165	See map	12	Gray mud
166	See map	10.5	Gray mud
167	See map	7.5	Brown sand and gravel
168	See map	10	Sand, pebbles, and iron-oxide concretions.
	The island of North Trout Lake lies between 167 and 168. East shore of island rocky for about 50 feet off shore.		
169	See map	17.5	Gray gyttja
170	See map	17.5	Gray gyttja
171	See map	14	Iron-oxide concretions

RANGE 7

Range 7 is across the south end of South Trout Lake from the east shore to Island No. 6.

Station	Distance from shore (Meters from E. shore)	Depth of water (Meters)	Sediments
172	54	3	Sand, gravel, and boulders
172a	80	6	Sand
172b	108	6	Sand
172c	135	13	Sand
173	165	27	Gray gyttja
174	190	27	Gray gyttja
175	315	29	Gray gyttja
176	400	29	Gray gyttja
	(Meters from island)		
177	340	27	Gray gyttja
178	315	20	Gray gyttja
179	270	22	Gray gyttja
180	225	18	Gray gyttja
181	195	18	Sandy gray gyttja
182	135	20	Gray gyttja
183	110	18	Gray gyttja
184	85	16	Gray gyttja
185	50	10	Sandy gray gyttja

RANGE 8

Range 8 extends from the southwestern shore of South Trout Lake to Island No. 5. The lake is extremely shallow to 360 meters from the shore, and the bottom is covered with sand, gravel, and boulders.

Station	Distance from shore (Meters from S.W. shore)	Depth of water (Meters)	Sediments
186	425	9	Gray gyttja
187	540	10	Gray gyttja
	(Meters from Island)		
188	360	10	Gray gyttja
188a	290	3	Sand and pebbles

From 188 to the shore of the island the bottom sediments are sand, gravel, and boulders.

RANGE 9

Range 9 extends from the northwestern shore of South Trout Lake across the deep part of this lake to Island No. 4. From the northwest shore to the depth of 12 meters the sediments from the shore outward are sands.

Station	*Distance from shore* (Meters from N.W. shore)	*Depth of water* (Meters)	*Sediments*
189	240	17	Gray gyttja
190	290	17	Gray gyttja
191	330	17	Gray gyttja
192	420	17	Gray gyttja
	(Meters from Island)		
193	330	17	Gray gyttja
194	215	18	Gray gyttja
194a	180	13	Probably iron-oxide crust
194b	160	5	Sand
	Sand extends from 194b to the shore.		

RANGE 10

Range 10 extends across the middle of North Trout Lake from the east to the west shore.

Station	*Distance from shore* (Meters from E. shore)	*Depth of water* (Meters)	*Sediments*
195	90	6	Sand
195a	250	12	Sand
196	340	24	Gyttja
197	500	29	Gyttja
198	Halfway between shores	28	Gyttja
	(Meters from W. shore)		
199	540	28	Gyttja
200	360	22	Gyttja
201	270	18	Sand
202	180	17	Sand
203	85	8	Sand

RANGE 11

Range 11 extends across the northern part of North Trout Lake from the bay on the west side to the mouth of the creek on the east shore.

Station	*Distance from shore* (Meters from W. shore)	*Depth of water* (Meters)	*Sediments*
204	65	2	Sand
205	120	7	Sand
206	180	9	Sand
207	290	11	Sandy gyttja
208	330	9	Sand
208a	400	9	Sand

Station	Distance from shore (Meters from W. Shore)	Depth of water (Meters)	Sediments
209	450	11	Gyttja
210	540	12	Gyttja
211	630	13	Brownish-gray gyttja
212	900	24	Gray gyttja
	(Meters from E. shore)		
213a	540	27	Gray gyttja
214	450	26	Gray gyttja
215	360	26	Gray gyttja
215a	270	23	Probably iron-oxide crust
215b	205	18	Probably iron-oxide crust
215c	105	4	Gravel and cobble bottom

RANGE 12

Range 12 extends across the north end of North Trout Lake, from east to west.

Station	Distance from shore (Meters from E. shore)	Depth of water (Meters)	Sediments
216a	90	1	Sand
216b	180	3	Sand and gravel
216c	270	10	A little sand, perhaps an iron-oxide crust
216d	360	10	A little sand, perhaps an iron-oxide crust
216	420	13	Gray sand
217	495	14	Gray gyttja
	(Meters from W. shore)		
218	540	17	Gray gyttja
219	395	20	Gray gyttja
220	270	14	Sand
221	150	8	Sand
221a	120	2.5	Sand

DESCRIPTION OF SOME TROUT LAKE SANDS

It seems desirable to describe in detail some of the samples of sediments acquired from the bottom of Trout Lake in order to show why certain generalizations cannot be made from the analyses.

SAMPLE 74

Sample 74 was acquired from Range 3 of South Trout Lake in water 20.5 meters deep. The sample contains iron concretions, pebbles coated with iron oxide, sand, and fragments of vegetable matter.

	Per cent
>4 mm. Iron concretions, nodules of sand cemented with iron oxide, a few iron-oxide coated pebbles, and some fragments of plants	26.54
2–4 mm. Same as the 4 mm. dimension with the addition of some pebbles not coated with iron oxide	7.70
1–2 mm. Mostly quartz sand, some particles composed of other minerals, some small iron-oxide concretions, and some iron-oxide-cemented aggregates of sand	7.03

		Per cent
½–1 mm.	Mostly quartz sand, a few concretions of iron oxide	11.33
¼–½ mm.	Mostly angular to subrounded quartz sand, none coated with iron oxide	20.46
⅛–¼ mm.	As ¼ to ½ mm.	22.92
1/16–⅛ mm.	Particles of angular quartz and feldspar with small particles of iron oxide	1.2

SAMPLE 78

Sample 78 was collected from Range 3 on Trout Lake in water 1 meter deep.

		Per cent
>8 mm.	17 pebbles of which four are up to 25 mm. long. One pebble composed of vein quartz, the other of basic igneous rocks	13.63
4–8 mm.	Pebbles of basic igneous rocks with four of vein quartz	1.91
2–4 mm.	Granules of basic igneous rocks, little rounded, some granules of quartz, four coiled gastropods, and some fragments of plants	2.94
1–2 mm.	Mostly composed of angular to subangular particles of quartz and some fragments of plants. Many particles of dark mineral or rock	4.96
½–1 mm.	Mostly angular particles of quartz	14.02
¼–½ mm.	Mostly angular particles of quartz	49.29
⅛–¼ mm.	Mostly angular particles of quartz	11.69
1/16–⅛ mm.	Angular particles of quartz and a considerable variety of other minerals	1.54

SAMPLE 81

Sample 81 was obtained on Range 3 of South Trout Lake in water of 3.5 meters depth.

		Per cent
>4 mm.	Fragments of grass and weeds	0.5
	12 pebbles of rock	0.8
2–4 mm.	About one tenth plant fragments, nine tenths particles of rock and minerals	4.9
1–2 mm.	About one-fifteenth plant fragments, the other part sands which are mostly quartz, but some other minerals and rocks	7.1
½–1 mm.	A little plant matter, most particles of angular to subangular quartz, but some particles of dark and pink minerals	22.2
¼–½ mm.	Similar to ½–1 mm.	49.1
18–¼ mm.	Mostly angular particles of quartz, but some dark mineral	11.8
1/16–⅛ mm.	Over one-fourth of the weight of the fraction is composed of organic matter. The mineral matter is mostly light colored but dark minerals are present	3.6

SAMPLE 94

Sample 94 was acquired in South Trout Lake on Range 3 in water with a depth of 4.5 meters.

		Per cent
>4 mm.	Plant fragments compose one half by weight. Inorganic matter consists of 3 pebbles of which one is granite, one feldspar, and one gneiss	2.5
2–4 mm.	Over half by weight consists of plant fragments; the inorganic part consists of 19 granules of which one is feldspar, four quartz, and others rock	2.4
1–2 mm.	About one half of volume consists of plant fragments, the rest mostly angular subrounded particles of quartz	5.0

		Per cent
½–1 mm.	One fifth to one fourth of volume consists of plant fragments, the remainder of angular to subrounded particles of quartz	15.6
¼–½ mm.	Contains a little plant material, rest angular particles of quartz with a few other minerals	52.7
⅛–¼ mm.	Sample of as ¼–½, but particles all angular	19.0
1/16–⅛ mm.	Fraction as ⅛–¼	2.8

SAMPLE 121

Sample 121 was collected in South Trout Lake on Range 4 in 14 meters of water. Many of the particles are iron oxide-coated. One iron-oxide-coated pebble is biscuit-shaped, about 50 mm. in diameter in two dimensions, and not over 12 mm. thick. The pebbles are of various compositions with feldspars, dark porphyry, basalt, jasper (iron formation), and greenstone common, most not coated with iron oxide.

		Per cent
>4 mm.	Pebbles of various kinds of rocks to over 7 mm. in diameter, little or no quartz. Most poorly rounded	63.50
2–4 mm.	Mixture of various kinds of pebbles, but several of quartz	7.78
1–2 mm.	About one third quartz, one third pink minerals, and one third basic igneous rock	6.26
½–1 mm.	Mostly quartz, about a third dark and pink minerals	9.0
¼–½ mm.	Mostly quartz, few dark and pink minerals	10.42
⅛–¼ mm.	Mostly quartz and with a considerable variety of dark minerals	2.33
1/16–⅛ mm.	Composed dominantly of dark minerals and considerable powdery iron oxide	0.71

SAMPLE 164

Sample 164 was collected on Range 6 in North Trout Lake in water 8 meters deep. The analysis is as follows:

		Per cent
>4 mm.	15 pebbles with diameters greater than 6.5 mm. and composed either of jasper (iron formation) or greenstone, 1.98%. Two sticks and a pine cone .11%, and pebbles 4 to 6.5 mm. in diameter consisting of schist, feldspar, greenstone and a few of quartz, 34.98%. Total	37.07
2–4 mm.	Particles composed of rocks of a considerable variety of which some are quartz and feldspar	10.83
1–2 mm.	Particles mostly rocks, some quartz, most not well rounded	9.75
½–1 mm.	About one half angular to rounded particles of quartz, some particles of feldspar and rock	15.21
¼–½ mm.	Mostly composed of quartz, particles rounded to angular	23.37
⅛–¼ mm.	Mostly angular particles of quartz	3.12
1/16–⅛ mm.	Composed mostly of angular particles of quartz, some iron oxide, and many particles of opaque minerals	0.65

SAMPLE 167

Sample 167 was collected in North Trout Lake in water 7.5 meters deep and on Range 6.

		Per cent
>16 mm.	Two pebbles of basic igneous rock, rounded	6.93
8–16 mm.	Pebbles of basic igneous rocks, rounded	16.84

		Per cent
4–8 mm.	Five pebbles of quartz, others mostly basic igneous rock, greenstone, and jasper (red chert), rounded	14.08
2–4 mm.	As 4–8 mm., but more pebbles of quartz	12.50
1–2 mm.	Particles of a wide variety of rock, but many of quartz, rounded	11.33
½–1 mm.	More than half quartz, few well rounded, some feldspar and the rest composed of dark minerals or rocks	14.66
¼–½ mm.	As ½ to 1 mm., mostly angular	18.10
⅛–¼ mm.	As ½ to 1 mm., mostly angular	4.63
1/16–⅛ mm.	About half angular particles of quartz, rest rock	0.93

SAMPLE 168

Sample 168 was collected in North Trout Lake in water 10 meters deep on Range 6.

		Per cent
>8 mm.	Pebbles to 25 mm. in diameter, all black rock or red flint, rounded	69.45
4–8 mm.	Pebbles of black rock and red flint with a few of quartz, rounded	10.73
2–4 mm.	Particles of black rock, red flint, and a few of quartz, rounded	3.89
1–2 mm.	Particles of black rock, red flint and quartz, moderately well rounded	2.89
½–1 mm.	More than three-fourths of angular to subrounded quartz, rest other light-colored minerals and pieces of rock	3.75
¼–½ mm.	Mostly angular and subangular particles of quartz	5.70
⅛–¼ mm.	Mostly angular particles of quartz	2.60
1/16–⅛ mm.	Mostly angular particles of quartz, but a considerable variety of minerals is present	0.99

SAMPLE 220

Sample 220 was collected in North Trout Lake in water 14 meters deep on Range 12.

		Per cent
>1 mm.	About half fragments of plants	0.32
½–1 mm.	Mostly quartz but with many black minerals, particles angular to subrounded	1.93
¼–½ mm.	Quartz with many particles coated with iron oxide. Contains small, hollow, spherical, black objects which seem to be organic	11.13
⅛–¼ mm.	Mostly quartz, a few particles coated with iron oxide, and some particles of black minerals	69.55
1/16–⅛ mm.	Nearly all quartz or light-colored minerals of which some are feldspar; all angular	17.07

SAMPLE 221

Sample 221 was collected on Range 12 in North Trout Lake in water 8 meters deep.

		Per cent
>2 mm.	Three small pieces of black rock	0.34
1–2 mm.	Six particles of which two are quartz and 4 rock	0.22
½–1 mm.	About half quartz, some small fragments of plants	1.32
¼–½ mm.	Almost entirely composed of angular particles of quartz	29.39
⅛–¼ mm.	Almost entirely composed of angular particles of quartz	53.80
⅛–1/16 mm.	Most angular particles of quartz, but a variety of other mineral	14.92

These analyses show that there is much variation in size, mineral content, and content of organic matter. Plant matter is not always present, but its presence always influences the results of a mechanical analysis. The coating of iron oxide on many samples also affects the mechanical composition of a sample. Summaries of the sands analyzed are given in Table 1.

TABLE 1.—*Summaries of analyses of some Trout Lake sands*

No.	74	78	81	94	121	164	167	168	220	221
Depth (meters)	20.5	1	3.5	4.5	14	8	7.5	10	14	8
Distance from shore (meters)	140	16	90	450	315	60	50	50	270	120
										per cent
>4 mm.	26.5	15.5	1.3	2.5	63.5	37.0	37.9	80.2	0.0	0.0
2–4	7.7	2.9	4.9	2.4	7.8	10.8	12.5	3.9	0.0	0.4
1–2 mm.	7.0	5.0	7.1	5.0	6.3	9.8	11.3	2.9	0.3	0.2
½–1 mm.	11.3	14.0	22.2	15.6	9.0	15.2	14.7	3.8	1.9	1.3
¼–½ mm.	20.4	49.3	49.1	52.7	10.4	23.4	18.1	5.7	11.1	29.4
⅛–¼ mm.	22.9	11.7	11.8	19.0	2.3	3.1	4.6	2.6	69.6	53.8
1/16–⅛ mm.	1.2	1.6	3.6	2.8	0.7	0.7	0.9	1.0	17.1	14.9

If one attempts correlation of the dimensions of the sands with depth of water, it will be observed that the sample with the greatest percentage of particles above 4 mm. in diameter (168) was collected beneath 10 meters of water and 50 meters from the shore. This sample has 80 per cent in this size range. The sample (121) with the second largest percentage in this size range was collected beneath 14 meters of water and 315 meters from shore. In other words, two of the samples acquired from the greatest depths, with the one exception of 74, contain the largest percentage of particles above 4 mm. in diameter. The sample with no particles above 2 mm. in diameter (220) was acquired beneath 4 meters of water, and this is still more striking in that only a very small percentage of this sample is larger than ¼ mm. Sample 221 is fully as striking, as it was acquired beneath 2.5 meters of water.

Correlation with distance from shore also shows peculiarities. The sample of smallest dimension (220) was taken 270 meters from shore, the one of largest dimension was acquired at 50 meters. The sample with second largest dimensions was acquired 315 meters from shore, the next to the greatest distance from shore. The sample (94) from the greatest distance from shore (450 meters) is composed of particles larger than those in samples 220 and 221 with distances from shore of 270 and 120 meters respectively. Sample 78 with least distance from shore and least depth is much finer than samples 74, 121, 164, 167, and 168, all from greater distances from shore and greater depths of water.

It is quite obvious that depth and distance from shore are not the only factors determining coarseness of the sands. Exposure to waves and directions of winds must play some part. If these samples are examined from the point of view to such exposure, the following relations are shown. Sample 74, from the south end of the east shore of South Trout Lake in 20.5 meters of water, is composed of coarser sand than sample 78, from the west shore on the other end of the range and a depth of

only 1 meter. The station of sample 74 borders a deeper part of the bottom than the station of sample 78 and seems to be in a more exposed position which may account for the sample being composed of larger particles. Sample 81 from a little deeper water than sample 78 and in the same part of the lake is of finer materials than sample 78. Sample 94 from southeast of Island No. 5 is from an exposed position and in moderately shallow water but contains very few large particles. There should be considerable. Sample 121 was collected from an exposed position on the north side of North Trout Lake east of the Narrows. Its coarseness is in harmony with the locality of acquirement. Sample 164 was collected in shallow water a short distance from the shore in the entrance to the bay on the southwest corner of North Trout Lake. It should and does contain considerable coarse sediment, but sample 167 on the same range from much deeper water is composed of somewhat larger particles, whereas sample 168 on the same range and from somewhat deeper water is still coarser in composition. These last two samples, however, are near the island in North Trout Lake which probably accounts for the coarseness. Samples 220 and 221, both from moderately deep water and in considerably exposed positions, are composed of very fine sediments, whereas much coarser sediments would be expectable.

THE SANDS OF TROUT LAKE

Generally speaking, the sands of Trout Lake may be described as not well sorted. Few samples were collected which did not contain some granules, and in many samples even pebbles were present. In some samples the sorting is excellent, but these samples contain only sands of the smaller dimensions. The constituent minerals of the sands are mostly quartz, but particles of white and pink feldspar are always present, and there are always particles of dark minerals or rock. The dark particles in a few samples may approximate 1 to 2 per cent. It seems likely that the sands have had three different histories. Nearly every sample contains particles in the size range of about ½ mm. which are extremely well rounded and either spherical or nearly so. The surfaces of most of these particles are minutely pitted. These sands have had a longer history of separation from the parent rock than the other particles. All samples contain subrounded particles; the quantity is small in some samples although always greater than that of the highly spherical particles. The subrounded particles exhibit little minute pitting or frosting. Particles of the third group are angular or only slightly rounded. These particles are those most abundant in most samples. These sands have not experienced much transportation after release from the parent rock for at least the larger dimensions, or they were transported by agencies which did not permit contact with other particles. Particles ⅛ mm. or less in diameter are angular, and they could not become rounded to any great degree no matter what the method of transportation.

The immediate parents of the larger angular particles are probably some of the igneous rocks over which the Wisconsin glacier passed. The subrounded particles may have had a longer history, and their parents may have been sedimentary rocks. The highly spherical and highly rounded particles probably had sedimentary parents, and at some time in their history they were transported by the wind.

One may only speculate as to the systems of rocks to which the sedimentary parents belonged. The St. Peter sandstone (Ordovician) contains abundant particles of the characters noted, and perhaps this formation was the sedimentary parent and at one time extended far to the north of the present distribution. The Cambrian formations of the upper Mississippi Valley also contain well-rounded and frosted grains of sand. Perhaps these also once extended far north of the present distribution and were the parents of the well-rounded grains. Whatever the parent, the particles came from the north on their last journey, and formations capable of supplying them must now exist or once did exist to the north.

The granules which are common to abundant in many of the samples are largely pieces of rock or vein quartz. A few are fragments of feldspar. The rocks are of many varieties. Basalt and iron formation (cherty iron carbonate or red flint or jasper) are those common. Pebbles are almost entirely composed of rocks although a large fragment of feldspar was found in one sample, and a few pebbles of vein quartz were found. Most large particles seem to have been derived from basic igneous rocks, but particles of acidic igneous rocks and granite porphyry are not uncommon. Pebbles of schist, greenstone, and metamorphosed sediments are common. Granules and small pebbles are not particularly well rounded; many are angular, and most are subangular. Transportation has been relatively short. Large pebbles and the cobbles present in many beach and offshore deposits are generally rounded. A considerable number of the offshore sands contain small concretions composed of sands cemented with iron and manganese oxides. These are ellipsoidal to spherical in shape and have rough surfaces.

Eighty-two samples of sands were subjected to mechanical analysis. Only 17 of the samples are fairly well sorted. The range of dimension of particles in most samples is wide. This is shown by the coefficients of sorting shown in Table 2 which presents the first, second, and third quartiles, and coefficients of sorting and skewness of the sands from the offshore and sandy bottoms of Trout Lake.

SPUD SAMPLING

The sediments of South Trout Lake were sampled with a spud sampler at 32 stations. The work was done mainly between the islands and the east shore, but some sampling was done west of the islands. The maximum thickness was found in the deep part of the lake between the Biological Laboratory and Island No. 4. The depth of water was 32 meters, and the gyttja was penetrated for about 6 meters (19 feet) without reaching bottom. Disregarding sampling done in shallow depths where the bottom is sand, or the gyttja is only a few inches to a few feet thick, the gyttja was penetrated in deep water at only four stations. Three stations are on the east side of South Trout Lake between the mouth of Allequash Inlet and the Biological Laboratory in depths of water from south to north of 25, 22.5, and 25.5 meters. Sand was encountered in these stations in the order given at 2.3, 3.3, and 2.5 meters. The fourth station is between Islands Nos. 1 and 6 at a depth of 25 meters where gyttja 2.55 meters thick rests on sand. At other places in the deep parts of South Trout Lake the base of the gyttja was not found. The gyttja was penetrated without reaching bottom between Island No. 6 and the Biological Laboratory at the

TABLE 2.—*First, second and third quartiles, coefficients of sorting and skewness, and megascopic descriptions of coarse sediments of Trout Lake*

Sample number	Q1	Q2	Q3	So	Sk	Macroscopic description
2	.13	.19	.24	1.35	.86	Sands to fine gravel, some sticks, bark, mostly quartz, angular.
3	.14	.18	.35	1.60	1.34	Sands to granules, little organic matter, mostly angular quartz, 2–3% dark mineral.
4	.088	.125	.188	1.40	1.1	Seems well sorted, dirty, dark brown, mostly angular quartz.
6	.138	.216	.375	1.61	2.41	Clean sand, few granules, mostly quartz, angular
7	.084	.121	.181	1.4	.	Gray sand, well sorted, some granules. Mostly angular quartz.
7a	.144	.203	.35	1.5	1.1	Sands to granules, mostly angular, rounded quartz pebbles up to a centimeter in diameter, some organic matter.
9	.163	.219	.375	1.5	1.3	Poorly sorted, yellow-brown, quartz granules common, 2% rounded.
12	.475	2.4	3.2	2.6	2.6	More than half pebbles and cobbles to more than 25 mm. longest diameter, mostly basic, some granite
14	.156	.238	1.2	2.8	3.1	Half pebbles of basic igneous rocks, one pebble of chert contains a section of a fossil, sands brown, some iron-oxide-coated granules.
15	.162	.238	.55	1.8	1.6	Poorly sorted, pebbles to 12 mm. diameter, sands and granules little rounded quartz
16	.138	.194	.288	1.4	1.1	Many granules, some small pebbles, mostly angular, sands mostly quartz.
17	.094	.143	.206	1.5	.93	Fine quartz sands, angular, a little plant matter, a few granules.
18	1.25	1.35	1.65	1.1	1.1	Mixture of gravel and sand, large particles various.
19	.185	.325	.80	2.1	1.4	Sands, granules, and small pebbles, sands mostly angular, mostly quartz.
20	.15	.242	.475	1.8	1.2	Poorly sorted sands to granules, angular mostly, some granules iron-oxide-coated.
21	.103	.169	.245	1.5	1.1	Sands with occasional small granules, mostly angular quartz.
27	.188	2.20	3.10	4.1	.12	Mixture of sands and pebbles of wide variety of composition, angular to subangular.
28	.097	.135	.198	1.4	1.1	Well sorted, small percentage of grains rounded, mostly quartz.
29	.125	.185	.24	1.4	.85	A few pebbles of various kinds of rocks, one granite to 13 mm. diameter, not well sorted, sands mostly angular, quartz.

TABLE 2.—*Continued*

Sample number	Q1	Q2	Q3	So	Sk	Macroscopic description
30	.164	.23	.405	1.5	.83	Sands with many granules, mostly angular quartz, some rounded.
31	.150	.198	.247	1.3	.94	Sands up to 13 mm. diameter, large particles not common, mostly angular quartz.
32	.135	.203	.39	1.7	1.2	Poorly sorted, with pebbles to 13 mm. sands mostly angular, a few highly spherical.
33	.175	.24	.40	1.5	1.2	Well-sorted sands, mostly angular quartz, some highly spherical and pitted.
34	.175	.238	.375	1.4	.8	Mostly angular quartz, well-sorted sands.
35	.163	.225	.35	1.4	1.1	Mostly angular quartz with a high content of pink mineral, some grains well rounded.
42	.170	.231	.40	1.5	1.3	Poorly sorted, sands to cobbles, mostly angular to subangular sands, a few highly spherical and pitted.
43	.175	.200	.245	1.2	1.1	Sands with a few granules, some plant matter, mostly angular quartz.
46	.156	.213	.375	1.5	1.3	Sands and pebbles to 13 mm. diameter, pebbles of various rocks, sands mostly angular quartz.
47	.141	.203	.34	1.5	1.1	Sands and granules, sands mostly angular quartz.
49	.163	.207	.36	1.5	1.4	Sands and granules, sands mostly angular quartz.
50	.119	.185	.245	1.4	.88	Sands and granules, sands mostly angular quartz.
52	.231	2.25	3.30	3.8	1.5	Sands to pebbles, pebbles mostly dark rocks, vein quartz and some feldspar, sands mostly angular quartz.
53	.136	.193	.245	1.3	.89	Angular to subangular quartz sands with a few granules.
54	.122	.215	.70	2.7	1.8	Poorly sorted, many pebbles and granules. Sands mostly angular to subangular quartz.
55	.123	.237	.42	1.8	.93	Well-sorted sands with some granules, sands mostly angular to subangular quartz.
56	.109	.163	.219	1.4	.89	Well-sorted, mostly angular quartz sands.
60	.150	.203	.412	1.6	1.5	Mixture of sands and granules, some organic matter. Sands mostly quartz and angular.
61	.150	.211	.412	1.6	1.4	Mixture of quartz sands and granules. Granules seem to be largely concretions of iron oxide.

TABLE 2.—*Continued*

Sample number	Q_1	Q_2	Q_3	So	Sk	Macroscopic description
71	.105	.163	.225	1.4	.88	Mostly angular quartz sands, some well rounded and pitted.
73	.109	.187	.45	2.0	1.4	Mixture of many granules and angular quartz sands. Some sands well rounded.
74	.130	.45	2.10	4.0	1.3	Mixtures of sands and iron-oxide concretions with some pebbles not coated with iron oxide. Color brown.
74	.162	.238	.495	1.7	1.4	This is an analysis of sample 74 with the concretions and pebbles removed.
78	.162	.225	.412	1.6	1.3	Mostly angular quartz sands with many rock granules which are mostly particles of minerals.
81	.150	.213	.375	1.6	1.2	
84	.155	.231	.475	1.7	1.4	Mixture of sands and pebbles, rock with a vein quartz pebble to 12 mm. diameter. Sands mostly angular to subangular.
90	.092	.138	.206	1.5	.99	Well sorted, angular, mostly quartz sands, many particles above 4 mm. with iron and manganese oxide coatings.
91	.138	.194	.312	1.5	1.1	Mixture of sands to pebbles with pebbles up to 12.5 mm. in diameter. Sands angular to subangular, some well rounded.
92	.113	.169	.225	1.4	.89	Sands with a few granules and pebbles, sands little rounded.
93	.100	.150	.213	1.4	.94	Well sorted, angular to subangular, mostly quartz sands.
94	.131	.196	.253	1.4	1.4	
95	.100	.150	.213	1.4	.94	Filled with fine-grained organic matter, sands mostly angular quartz.
96	.113	.163	.225	1.4	.95	Angular, mostly quartz sands, some subrounded.
97	.137	.188	.244	1.3	.94	
98	.120	.175	.234	1.4	.91	Angular, mostly quartz sands with much finely divided organic matter.
99	.119	.175	.225	1.4	.87	Well sorted, mostly quartz sands, well rounded in upper dimensions. Some grains pieces of rock.
100	.083	.122	.188	1.5	1.2	Fine-grained, angular, mostly quartz sands.
103a	.094	.149	.231	1.6	.98	Mostly angular quartz sands with some granules.
104	.113	.156	.206	1.3	.99	Well sorted, mostly angular quartz sands.
105	.113	.172	.226	1.4	.87	Mostly angular quartz sands with considerable plant stems and bark, and one small coiled gastropod.

TABLE 2.—*Continued*

Sample number	Q1	Q2	Q3	So	Sk	Macroscopic description
106	.124	.173	.219	.3	.91	Sands and granules, some bark, stems, and leaves, sands mostly quartz and angular.
107	.131	.178	.225	1.3	.96	Sands and iron-oxide concretions, concretions to 15 mm. diameter, sands mostly quartz and angular.
109	.163(?)	.231	.475	1.7	1.5	Brown sands and granules, sands mostly quartz and angular, granules vein quartz and rock.
120	.100	.150	.218	1.5	.97	Fine angular, quartz sands.
121	1.80	2.60	3.80	1.4	1.0	
122	.113	.188	.231	1.4	.74	Sands and granules, some stems. Sands mostly quartz.
125	.124	.181	.239	1.4	.90	Sands with some granules, somewhat dirty, sands mostly quartz.
126	.109	.175	.238	1.5	.85	Poorly sorted, many granules, mostly in lower dimension, sands mostly quartz.
127	.109	.175	.244	1.5	.90	Sands and granules with some stems. Sands mostly quartz and mostly angular.
128	.100	.200	.275	1.7	.69	Mostly angular quartz sands and rock granules. Some well-rounded grains.
129	.109	.169	.238	1.5	.94	Angular quartz sands with a few granules. The sample contained some lumps of dirt.
130	.126	.181	.241	1.3	.93	Angular, mostly quartz sands, well sorted.
36	.156	.231	.392	1.6	1.14	Sands to small pebbles. Most quartz grains angular, some highly rounded.
139	.116	.148	.244	1.4	1.3	Sands to pebbles, some bark and stems, sands mostly quartz and angular.
141	.161	.244	.625	1.95	1.7	Sands and granules with much plant matter. Little rounding, considerable dark mineral.
164	.122	.525	2.1	4.0	.93	
167	.138	1.05	3.8	5.2	.46	
168	3.0	5.8	8.0	1.6	.71	
181	.113	.188	.287	1.6	.92	
184	.081	.114	.175	1.5	1.1	
185	.128	.181	.238	1.4	.93	
195	.091	.163	.263	1.7	.89	
200	.056	.081	.109	1.4	.93	
201	.062	.095	.156	1.6	1.1	
201	.056	.081	.109	1.4	.93	
202	.069	.094	.119	1.3	.93	
203	.078	.105	.156	1.4	1.1	
204	.091	.119	.191	1.1	1.2	
204	.097	.138	.200	1.4	1.0	
205	.088	.116	.175	1.4	1.24	

TABLE 2.—*Continued*

Sample number	Q1	Q2	Q3	So	Sk	Macroscopic description
205	.097	.138	.194	1.4	.99	
206	.084	.113	.169	1.4	1.1	
207	.091	.138	.219	1.6	1.0	
208	.091	.138	.200	1.5	.95	
208a	.103	.156	.205	1.4	.85	
216	.097	.150	.225	1.5	.97	
220	.072	.094	.110	1.2	.89	
221	.072	.113	.150	1.4	.84	

depth of 30 meters to 3 meters (10 feet), at 29.5 meters to 4.75 meters (16.5 feet), at 29 meters at two places to 3.3 meters (11 feet), between the mouth of Allequash Inlet and Island No. 1 at 33.5 and 34 meters to 4.7 meters (14 feet) and 4.3 meters (14.5 feet) respectively, and between Allequash Inlet and Island No. 2 to 4.7 meters (15 feet) in depth of water of 32.5 meters. Between Islands Nos. 2 and 6 at the depth of 18 meters the gyttja was penetrated to the depth of 2.7 meters (9 feet) but was found to be gritty at the bottom suggesting that the base was being neared. Between Islands Nos. 1 and 6 gray sand was found beneath 2.55 meters (8.5 feet) of gyttja in water 25 meters deep. Between the west point of the channel between North and South Trout Lake and Island No. 3 in water 16 meters deep, the gyttja was penetrated for 4.2 meters (14 feet) without reaching the base.

The spud sampling indicates that the gyttja thins to nothing as the shores are approached, that there are numerous places where the thickness is of the order of 3 to 3.5 meters, and that in the deep places on the bottom of the lake the thickness exceeds 5.7 meters (19 feet).

FINE-GRAINED SEDIMENTS OF TROUT LAKE

The fine-grained sediments from the bottom of Trout Lake have been designated sludge by the senior writer for about a decade. Recently Deevey has argued that these sediments fall within the meaning of the Swedish term of gyttja. The writers accept this suggestion and the fine-grained, organic-rich sediments from the bottom of Trout Lake are so designated. The Ekman sampling resulted in obtaining 221 samples of the bottom sediments, of which 99 are gyttja. The gyttja samples were studied by such methods as seemed hopeful of yielding results of significance. These are described on the pages which follow.

MEGASCOPIC APPEARANCE OF GYTTJA FROM TROUT LAKE

Samples 5, 8, 10, 11, 18, 19, 22, 23, 24, 25, 26, 36, 37, 38, 39, 44, 47, 51, 62, 63, 64, 65, 66, 67, 68, 69, 70, 75, 115, 116, 117, 118, 119, 128, 133, 144, 145, 146, 154, 159, 160, 161, 165, 166, 169, 173, 174, 175, 176, 177, 179, 180, 182, 183, 186, 187, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 203, 210, 211, 212, 213, 214, 215, 217, and 218 consist of gyttja, of which the gross color is black to very dark gray or greenish black. The major substance is a greenish-yellow gel in which

are enmeshed bits of inorganic matter, diatom tests, sponge spicules, and an occasional small shell.

Sample 163 is also gyttja but contains much grassy matter. Samples 178, 184, 195, 204, 205, and 208 consist of fine sand or silt with considerable organic matter like that of gyttja. The maximum dimension of the grains of sand is about $\frac{1}{4}$ mm., and many of the larger grains are frosted.

MECHANICAL ANALYSES OF GYTTJA

Not all samples of gyttja collected were analyzed, for reasons which will be given later. Two analyses were made of each sample of which the first was done with the Pipette method of Krumbein and the second with the Hydrometer-Pipette method of Hellman and McKelvey. Columns are arranged for sand-, silt-, and clay-size particles. An additional column gives results of some evaporations of the water containing the silt and clay after the sand had been removed by sieving.

It will be observed that the results of the two methods of analysis do not agree but, in general, the sums of the silt and clay content approximate the same quantity in the two methods. This is not the case in a few samples. In most samples the sum of the quantities of silt and clay do not agree with the quantities obtained by evaporation of the suspensions of silt and clay and drying of the residue. Only in four samples is there approximate agreement. It is thought that the organic matter in the sediments is responsible for the differences.

As previously noted, the most common substance in the wet gyttja is a pale greenish-yellow gel. This has great ability to buoy substances and to slow greatly the rate of settling of inorganic particles. The gel is evidently of organic origin. In addition to the gel the gyttja contains a considerable content of finely divided organic matter which does not readily settle, and its presence may have affected the rate of settling of inorganic particles. The gyttja when dried is hard, tough, and somewhat rubbery. It is ground to powder with considerable difficulty. A mechanical analysis of the powdered gyttja merely measures the perfection of crushing. Such an analysis may have value for some objectives but has little significance so far as the transportation and deposition of the materials of the gyttja are concerned. Mechanical analyses must be made before the gyttja is dried. The exact weight of the sample analyzed cannot be determined in advance of analysis except by weighing a vessel filled with the wet sediments and later weighing the same vessel filled with water. Weights were ordinarily determined by adding the weights of the several fractions obtained in the analysis. These weights have degrees of correctness in inverse ratio to the quantities of pale-greenish-yellow gel in the suspensions. They may be expected to be greatly in error if this quantity is large. The error is likely to be on the side of too large a quantity rather than too small.

If a suspension is evaporated, the gel shrinks to very small volume and loses most of any contained water. The finely divided plant and other organic materials also decrease in volume and weight through loss of water, and a figure of weight is obtained which is smaller than that indicated by the sum of the fractions of silt and

TABLE 3.—*Mechanical analysis of gyttja from Trout Lake*

Sample number	Sand (Per cent)	Silt (Per cent)	Clay (Per cent)	Weight of silt and clay by evaporation (Per cent)
5	62.87	0.04	37.09	30.99
	55.30	2.40	42.30	
18	0.96	2.40	96.64	78.7
	0.90	5.80	93.30	
38	trace	1.42	98.58	64.84
	trace	16.10	83.90	
39	trace	5.27	94.73	86.85
	trace	73.70	26.30	
70	20.44	3.16	76.40	65.44
	17.20	13.30	69.50	
128	trace	0.59	99.41	79.47
	trace	39.47	60.53	
145	1.78	1.22	97.00	64.41
	1.07	14.76	84.17	
146	1.73	0.22	98.05	62.04
	1.21	12.42	86.37	
165	54.47	0.31	55.22	35.13
	45.59	10.27	44.14	
173	14.80	6.18	80.02	
	10.45	7.85	81.70	
174	9.80	0.20	90.00	
	5.55	15.70	78.75	
175	1.50	1.70	96.80	
	2.47	17.50	80.03	
179	6.20	0.00	93.80	
	6.17	0.00	93.83	
180	22.25	17.95	59.80	
	22.44	49.96	17.60	
181	0.00	87.77	12.26	
	0.00	21.57	78.43	
182	47.20	50.75	3.05	
	34.30	50.07	15.63	

TABLE 3.—*Continued*

Sample number	Sand (Per cent)	Silt (Per cent)	Clay (Per cent)	Weight of silt and clay by evaporation (Per cent)
183	56.75	39.00	5.25	
	40.03	36.23	23.74	
186	56.75	39.00	5.25	
	30.85	39.15	30.00	
187	24.30	5.50	71.20	
	20.60	7.65	71.75	
188	19.75	0.00	80.25	
	17.00	0.00	83.00	
189	48.50	2.48	50.02	
	48.15	4.85	47.00	
192	6.14	1.17	92.69	93.86
194	15.26	2.14	82.60	79.10
197	1.55	7.45	91.00	
	1.80	1.20	97.00	
199	10.72	18.65	70.63	
	14.85	0.65	84.50	
200	27.90	2.10	70.00	53.72
	3.88	1.12	95.00	
209	37.70	4.60	57.70	59.40
	39.00	3.00	58.00	
210	68.38	28.94	2.68	27 46
	62.80	30.20	7.00	
211	74.50	0.80	24.70	24.81
212	71.20	7.00	21.80	53.72
	3.82	5.38	90.80	
217	18.60	60.70	20.70	61.77
	13.85	80.40	5.75	

clay size determined by the Pipette and Hydrometer-Pipette methods of mechanical analyses.

On the basis of the above analysis samples 192, 194, 209, and 210 should contain little gel, whereas samples 5, 18, 38, 39, 128, 145, 146, and 165 should contain a great deal.

The essence of the above discussion is that mechanical analyses of wet gyttja

TABLE 4.—*Organic matter in Ekman samples as determined by loss on ignition*

Stations	A (Per cent)	B (Per cent)
5, 8, 10, 11	21	21—
19	37.6	37
22–26	43	44
36–39	42	43—
44, 47	30	28
62–69	33	32
65, 70, 75	41	41
89–91	45	46
101	20	20
115	44	43.5
116–119	39	42
131	44	44
133	38	37— gray color, mostly diatoms
144–146	39	41
148	29	28
160	49.1	49.9
161–166	44	44
169	46—	46
173–179	43	43
180–189	25	27
191–194	41	41
196–199	42	42
210, 211, 212, 214, 215	18	20
213	44	44
Average.....	37.4	37.7

McKelvey's determinations of organic matter in gyttja from Trout Lake

Stations	Per cent
5	38.80
18	30.20
38	32.70
39	31.70
70	33.40
128	39.50
145	39.60
148	40.10
165	37.30
178	41.20
192	44.30
193	46.30
194	44.10
200	45.00
209	35.60
210	33.20
211	34.10
212	46.40
214	44.70
217	26.70
Average.....	38.24

are meaningless from the point of view of sedimentation, that drying and powdering of this sediment may fundamentally change the sizes of the particles from what they were at the times of deposition, and that mechanical analyses of gyttja do not permit reconstruction of the conditions of deposition.

TABLE 5.—*Organic and lignin content of some Eckman samples*

Stations	Organic content	Lignin part of organic matter	Nonligneous part of organic matter
5	51.55	21.54	78.46
18	56.64	18.27	83.73
38	59.91	24.81	75.19
39	51.07	19.99	80.01
70	55.98	15.34	84.66
128	69.52	20.47	79.53
145	55.61	23.59	76.41
146	50.94	24.45	75.55
148	62.19	27.34	72.66
165	63.15	22.71	77.29
178	56.32	27.44	72.56
192	50.07	19.46	80.54
193	60.37	24.96	75.04
194	54.86	28.00	72.00
200	56.34	21.60	78.40
209	58.34	26.58	73.42
210	49.84	24.01	75.99
211	52.96	18.59	81.41
212	52.70	30.95	60.05
214	55.67	30.39	69.61
217	41.22	21.66	78.34
Mean	55.48	23.29	76.81

The organic content of the gyttja was determined by ignition, two determinations being made of each sample, designated A and B in Table 4. The loss on ignition was estimated as organic matter. This is in error to some degree as there is some loss due to dehydration of diatom tests, sponge spicules, and clay minerals. Percentages of organic matter consisting of lignin are given in Table 5. Determinations were made according to the method of Steiner and Meloche. Results are only approximate.

The average water content of a large number of samples of gyttja obtained with the Ekman dredge is 92.5 per cent with a range from 79 to 96 per cent, the lowest moisture content being found in a sample obtained on Range 1 near the west shore.

CORE SAMPLES

Samples were taken with the Jenkins and Mortimer core sampler at 10 stations and with the Twenhofel core sampler at 7 stations for the purpose of obtaining quantity. Stations where the Jenkins and Mortimer sampler was used are indicated (Pl. 1) by the letters A, B, J, K, L, M, N, O, P, and Q. Places of collection with the Twenhofel sampler are indicated by the letters C, D, E, F, G, H, and I. Descrip-

tions of these several stations and any general information connected with them are given below. The location of station H was either not recorded on the field map, or it was erased therefrom in some way. The locations of the stations are shown by encircled points.

Station A. This station is in the east half of South Trout Lake in water 34.4 meters deep. The sediments were penetrated to the depth of 3 meters and consisted of greenish-gray to black gyttja containing recognizable plant remains. The bottom of the organic sediments may have been penetrated as the sampler could not be driven deeper, but nothing was found in the bottom of the core to indicate that this was the case.

Station B. This station is in the east half of South Trout Lake about 270 meters west of the east shore of the lake in water 31 meters deep. The sediments were penetrated to the depth of 4.1 meters and consisted of dark-greenish-gray to black gyttja. The core contained no macroscopic plant remains.

Station C. This station is in South Trout Lake, east part, in 35 meters of water. The sediments, consisting of dark gyttja, were penetrated for 3 meters.

Station D. Station D is in North Trout Lake in the small bay in the southwestern part in 5 meters of water. The sediments were penetrated for 3.5 meters and consisted of sand and gravel in the top and several inches of dark-gray gyttja below.

Station E. Station E is in the eastern part of South Trout Lake in 22.5 meters of water. The sediments were penetrated for 1.5 meters and were as follows:

9 inches pink sand and silt
6 inches dark gray silt
3 inches dark gray sand
41 inches dark gray and black gyttja

Station F. Station F is in the eastern part of South Trout Lake in water 29.8 meters deep. Sediments, consisting of dark gyttja, were penetrated for 3.2 meters.

Station G. Station G is in the eastern part of South Trout Lake in 32 meters of water. The sediments, consisting of dark-gray gyttja, were penetrated for 3 meters.

Station I. This station, in the deepest part of North Trout Lake, is in 27.5 meters of water. The sediments, consisting of dark gyttja, were penetrated for 4 meters.

Station J. Station J is in the eastern part of South Trout Lake in 28.7 meters of water. Sediments, consisting of dark-gray gyttja, were penetrated for 2.4 meters.

Station K. Station K is in the eastern part of South Trout Lake in water 25.5 meters deep. A core of 4.8 meters was obtained which consists of dark-greenish-gray to black gyttja showing no macroscopic plant materials. The bottom of the gyttja was not reached.

Station L. This station is in the eastern part of South Trout Lake in 23.3 meters of water. The sampler penetrated to 4.68 meters of dark greenish-gray to black gyttja without reaching the bottom of the deposit.

Station M. This station is in the northeastern part of South Trout Lake in water 22 meters deep. The sediments were penetrated for 2 meters. They consisted of dark gyttja.

Station N. Station N is in North Trout Lake in water 26 meters deep. Dark-greenish-gray to black gyttja was penetrated to the depth of 2.1 meters without reaching bottom. The sediments contained considerable sand at the depth of 1 meter.

Station O. This station is in the bay in the southwestern part of North Trout Lake in water with depth of 0.6 meter. The sediments were penetrated to the depth of 2.4 meters, and the core brought to the surface consisted as follows:

0–3 inches, grayish-brown gyttja
3 inches to 1 foot, yellowish-brown gyttja
1 foot to 3 feet, 9 inches, grayish brown gyttja
3 feet, 9 inches to 8 feet, yellowish-brown gyttja

Station P. This station is in the eastern part of South Trout Lake in water 18.5 meters deep and about 200 meters from the east shore. Dark-greenish-gray to black gyttja was penetrated to the depth of 3.6 meters without reaching the bottom. No macroscopic plant remains were seen in the deposits.

Station Q. This station is in the northwest part of South Trout Lake in 15 meters of water. The sediments were penetrated for 3.6 meters. They consisted of dark-greenish-gray to black gyttja. The bottom of the gyttja was not reached.

Table 6 gives the moisture content of the sediments of the cores for each foot of depth. The first figure in each column gives the moisture content of an Ekman sample collected at the same place as the core.

Table 6 shows that there is a gradual, but small, decrease of moisture with depth. The loss of water seems to some degree to be correlated with decrease in organic matter although this decrease is not conspicuous. Retention of so much organic matter suggests limited bacterial action.

Elimination of all water from the organic sediments—the gyttja—would reduce the maximum thickness found in any core to less than half a meter (1.5 feet). The time involved in the accumulation of this thickness represents most of the time since the retreat of the late Wisconsin glacier from the region of Trout Lake, a time generally estimated of the order of 15,000 to 25,000 years. This gives a very slow rate of accumulation.

Several of the cores were studied for lignin content, determined according to the method of Steiner and Meloche. Results are only approximate and are made more so because of the presence of opaline silica in the diatom shells and any hydrous silicates in the inorganic sediments, as both yield water. Results are given in Table 7, of which the first column gives the percentage of organic matter in the samples, the second the percentage of lignin in the organic matter, and the third, which is complementary to the second, the percentage of nonligneous organic matter in the organic matter. The nonligneous inorganic matter was determined by digestion in sulphuric acid, the ligneous part by ignition after the nonligneous part was removed. The ligneous percentage also includes any water contained in diatoms and inorganic sediments.

Cores A, B, J, K, and L have about the same content of organic matter. The organic matter is considerably less in core Q and very much less in core P. The average content of organic matter is shown in Table 8. The differences in organic

content of the sediments presents no difficulty of explanation and merely indicates that entrance of inorganic sediments is greater where the organic content is reduced. Core A has a smaller percentage of lignin as compared with the other cores. This is probably due to differences in the kinds of organic matter deposited. Core A was acquired from the deepest part of South Trout Lake in water 34.4 meters deep.

TABLE 6.—*Moisture content of the sediments of the cores*

Station	A	B	J	K	L	M	N	O	P	Q
Eckman	94.2	96.0	94.0	94.7	94.4	94.4	93.2	97.0	93.1	95.3
1	91.9	95.5	93.4	93.9	93.7	90.1	93.4	95.2	92.8	92.0
2	91.1	94.0	93.3	93.9	93.6	90.2	92.4	95.1	92.1	91.2
3	91.3	93.7	94.1	93.3	93.1	87.3	87.3	94.8	91.8	90.4
4	90.7	92.9	91.7	92.3	93.1	84.4	92.1	94.5	91.2	91.7
5	91.4	91.3	90.2	92.4	92.3	41.0	69.0	95.5	90.4	90.0
6	91.6	90.2	90.3	91.9	92.0	41.5	83.0	96.1	90.8	89.8
7	89.0	90.2	91.6	92.4	90.8		79.5	96.4	90.8	90.1
8	91.6	91.1	88.4	90.7	90.4			95.6	90.7	90.4
9	90.2	91.1		92.1	91.1				90.5	89.4
10	88.3	90.4		91.8	90.3				89.9	89.1
11		90.2		91.2	88.6				89.9	89.6
12		89.3		90.5	88.7				89.2	88.9
3		88.4		87.3	88.0					
14		89.3		88.3	89.1					
15				87.2	85.7					
Total av.	91.9	91.7	92.7	91.5	90.0	75.5	86.3	95.6	91.0	90.6
Av. cores	91.7	91.2	92.5	91.3	90.6	74.0	85.4	94.9	90.8	90.2
Depth of water in meters	34.4	31.0	28.7	25.5	24.3	22.0	0.5	24	18.5	20.5

In general, the lignin contents of each core are consistent with each other and differences may be readily explained as due to differences in the composition of plant materials originally deposited and, perhaps, to some degree to bacterial decomposition. As a rule, the sample derived from the top foot of a core has the smallest content of lignin. This is shown in cores A, B, K, P, and Q, but it is not the case in the other cores listed. It was anticipated that bacterial decomposition would have led to decrease of the nonligneous materials, and thus there was expected to be an increase of ligneous materials with depth. The fact that such decrease does not appear suggests that bacterial activity quickly ceases in the organic sediments of Trout Lake after they are buried.

The organic content of the cores was also studied through loss on ignition. Results are significantly lower, thus indicating that digestion in sulphuric acid removes substances other than the nonligneous part of the organic matter. If the loss on ignition is estimated as equalling the organic matter, which evidently is not exactly the case, and the ligneous fraction as determined by the Steiner and Meloche method

TABLE 7.—*Ligneous and nonligneous matter in core samples*

Depth in feet	Organic matter in samples (Per cent)	Organic matter composed of lignin (Per cent)	Organic matter not composed of lignin (Per cent)
	CORE (A)		
1	63.95	20.05	79.95
2	61.93	20.41	79.59
3	66.67	21.27	78.73
5	62.45	24.26	75.74
7	69.73	21.43	78.57
8	65.66	25.02	74.98
9	66.65	20.28	79.72
10	63.48	23.85	76.15
Mean	65.06	22.07	77.93
Max. departure from mean	4.67	3.05	3.05
	CORE (B)		
1	56.80	29.38	70.62
3	60.64	33.24	66.76
5	65.67	34.76	65.24
7	64.48	40.00	60.00
9	64.56	37.91	64.94
Mean	62.41	35.06	64.94
Max. departure from mean	5.61	5.68	5.68
	CORE (J)		
1	66.18	36.18	63.82
3	61.90	37.27	62.73
4	67.47	36.02	63.98
7	67.46	34.44	65.56
8	56.76	30.93	69.07
Mean	63.95	34.97	65.03
Max. departure from mean	6.19	4.04	4.04
	CORE (K)		
Eckman	60.56	29.61	70.39
3	59.42	40.17	59.83
5	62.88	39.47	60.53
7	65.63	40.79	59.21
9	67.00	35.05	64.95
11	62.83	33.17	66.83
13	61.27	30.58	68.42
14	57.32	33.95	69.42
Mean	62.11	35.35	64.65
Max. departure from mean	4.98	5.74	5.74

TABLE 7.—*Continued*

Depth in feet	Organic matter in samples (Per cent)	Organic matter composed of lignin (Per cent)	Organic matter not composed of lignin (Per cent)
	CORE (L)		
Eckman	53.28	33.70	66.30
3	69.02	31.19	68.81
5	65.48	42.57	57.43
7	67.90	34.89	65.11
9	61.83	30.66	69.34
11	56.11	31.83	68.17
13	59.60	30.32	69.68
Mean	62.20	33.59	64.41
Max. departure from mean	8.92	9.98	9.98
	CORE (P)		
Eckman	43.81	27.54	72.46
2	49.73	36.39	63.61
4	49.73	41.11	58.89
6	48.59	38.05	61.95
8	46.46	35.95	64.05
10	50.78	33.83	66.17
12	50.46	34.13	65.87
Mean	48.52	35.28	64.72
Max. departure from mean	4.71	7.74	7.74
	CORE (Q)		
1	50.46	30.15	69.85
3	53.82	31.25	68.75
5	54.01	37.28	62.72
7	55.39	34.50	65.50
10	53.84	31.78	68.22
11	53.57	32.78	67.22
Mean	53.51	32.95	67.05
Max. departure from mean	3.05	4.33	4.33
	Odd Samples		
	CORE (D)		
Eckman	56.91	25.66	74.34
	CORE (E)		
Eckman	61.36	24.56	75.44

TABLE 7.—*Continued*

Depth in feet	Organic matter in samples (Per cent)	Organic matter composed of lignin (Per cent)	Organic matter not composed of lignin (Per cent)
CORE (G)			
Eckman	65.29	27.98	72.02
CORE (I)			
Eckman	43.35	33.97	66.03
CORE (M)			
Eckman	57.24	26.51	73.49
1'9"–2'11"	44.46	20.64	79.36
CORE (N)			
Eckman	51.04	29.51	73.49
3	53.23	33.77	66.23

TABLE 8.—*Average content of organic matter and lignin in each core*

	Organic matter	Organic matter composed of lignin
A	65.06	22.07
B	62.41	35.06
J	63.95	34.97
K	62.11	35.35
L	62.20	33.59
P	48.52	35.28
Q	53.61	32.95
Mean		33.61

is based on this loss as total organic matter, the percentage of lignin in cores J, K, and L is as shown in Table 9. These percentages are not only larger than shown in Table 7, but the relations are not the same.

IRON AND MANGANESE DEPOSITS IN TROUT LAKE

The early sampling showed that considerable areas on the bottom of Trout Lake are covered with deposits containing much iron and manganese. Mr. Feray attempted to map the distribution of these deposits in the summer of 1942. The studies of Mr. McKelvey and Mr. Nelson showed large areas in deep water where samples could not be obtained and the dredges indicated "hard bottom." It was considered that these parts of the bottom were covered with large rocks although it was difficult to understand how this could be the case. The work of Mr. Feray proved that the places of "hard bottom" in deep water are covered with a solid crust containing a high content of iron and manganese. As previously noted, dredging must be done when the waters are relatively quiet, and ordinarily only 2

or 3 days of each week are suitable for work. This accounts for the fact that Mr. Feray gave over 2 months to mapping the iron and manganese deposits without bringing it to completion. Results are shown in Plate 3. It is known that additional iron and manganese deposits are present over the south half of South Trout Lake.

TABLE 9.—*Organic matter based on loss on ignition*

	Organic matter (Per cent)	Organic matter composed of lignin (Per cent)
CORE (J)		
1	51.60	69.92
3	52.30	71.26
5	51.70	69.66
7	44.00	78.27
CORE (K)		
Eckman	45.50	65.07
1	49.50	
3	48.00	83.68
5	53.50	73.77
7	53.20	77.05
9	50.00	70.10
11	47.00	70.57
13	42.00	72.85
14	43.50	78.04
CORE (L)		
Eckman	48.50	69.49
3	55.00	56.71
5	53.00	78.43
7	49.00	71.20
9	48.20	63.81
11	38.80	82.04
13	42.00	72.19

The mapping was done by mounting flags on anchored burnt-out electric light bulbs for floats. Positions of flags were determined by triangulation. The work was not completed due to the outbreak of the war which placed the geologic assistants in the military forces.

The iron and manganese deposits in Trout Lake can be placed in three general classes: solid crusts of unknown thickness over parts of the bottom, concretion-like crusts on pieces of rock associated with rocks which are not encrusted, and small concretionary bodies ranging in diameter to about half an inch. The concretions are scattered through muds and fine sands. The concretions had been previously noticed by Dr. Chancy Juday, late Director of the Trout Lake Biological Laboratory. The discovery of the crustal materials is new. A photograph of a crustal deposit on a large boulder is given in Plate 2.

Iron and manganese crusts over the bottom were found to range in depth from about 7 to 26 meters, although iron and presumably manganese oxide coatings are present on rocks in places to water level. Concretions range in depth from about 5 to 20 meters but probably extend as deep as the crustal deposits. Both the iron and the manganese are probably in the form of hydroxides, and they must have been

TABLE 10.—*Analyses of water of Trout Lake*

Depth (Meters)	SiO_2	Fe	Mn	O_2	CO_2
0	6.8	0.03	0.023	8.2	2.2
10	6.8	0.03	0.023	8.6	2.7
20	7.3	0.03	0.013	6.5	9.5
25	8.2	0.06	0.057	4.9	12.0
30	11.0	0.17	0.400	1.6	15.0
32	11.0	0.20	0.600	0.9	16.0
34	12.0	0.35	1.200	0.6	17.0

precipitated from the waters of Trout Lake. Analysis of the waters of this lake as of date of August 22, 1932, published by Juday, Birge, and Meloche gives the dissolved contents in milligrams per liter of water (Table 10).

It should be noted that the amounts of iron and manganese in solution are small. Considering the decrease of oxygen and the increase of carbon dioxide with depth it becomes somewhat difficult to understand how the two metals could have been deposited as oxides. Color of the deposits ranges from yellow to reddish black to black. Powdering of the dark deposits generally increases the extent of red. All crustal deposits are high in organic matter. Organic matter is also present in the concretions but in smaller quantities than in the crustal deposits.

The precipitation of both the iron and the manganese is referred to bacteria, and iron-precipitating bacteria are reported to have been found in the deposits. Both the iron and the manganese were probably leached from the outwash and till surrounding the lake and carried to the lake either as carbonates or as colloids.

Analyses of the iron and manganese deposits (number 1 of an iron and manganese crust collected at Feray station 262 in 20 meters of water and number 2 of iron concretions from Feray station 120, also in 20 meters of water) are given in Table 11. The determinations of the iron and manganese and a single determination of phosphorus were made of each sample by Mr. James Nichols in the chemical laboratory of the Department of Geology. Two determinations of phosphorus were intended, but only one was made when the quantity was found to be small. It was anticipated that the phosphorus content might be large, but this was found not to be the case. Determination of organic matter was by ignition which yields results probably in excess of fact as some loss on ignition probably arises from dehydration of diatom shells and hydrous silicates, and there may be some water in the iron and manganese compounds.

The iron is probably in the form of ferric hydroxide, and the manganese may correspond to psilomelane, of which Dana gives the approximate composition as

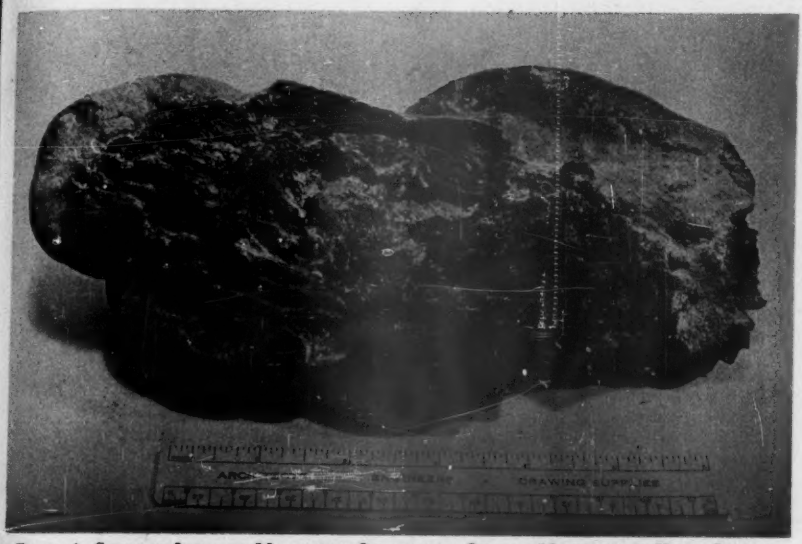


FIGURE 1. CRUST OF IRON AND MANGANESE OXIDES WITH ORGANIC MATTER OVER UPPER SURFACE OF LARGE COBBLE
Collected in water about 15 meters deep in South Trout Lake.

FIGURE 2. FRAGMENT OF SOLID CRUST FROM DEEP PART (20 METERS) OF SOUTH TROUT LAKE
Crust is part of "hard bottom" surrounded by gyttja. Specimens contain no sand. Left specimen—top; right specimen—side view of crust.

IRON AND MANGANESE DEPOSITS

MAP OF TROUT LAKE SHOWING DISTRIBU

Complete distribution has not been determined. It may be ass
as extensive as over the north half.

IBUTION OF IRON AND MANGANESE DEPOSITS

e assumed that deposits over the south part of South Trout Lake are

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H_4MnO_5. Bog deposits in Canada are stated by Hanson (1932) to have the manganese in the form of pyrolusite. The analyses show that in the crustal deposits manganese is present in excess of iron, that the iron and manganese together are just a little less than 50 per cent, and that the combinations of the two metals plus the organic matter approximate the whole of a deposit. It is known that a little silica is present.

TABLE 11.—*Chemical composition of the iron-manganese crusts and concretions* (In per cent)

	1		2	
Organic matter	20.98	20.89	11.01	9.80
Metallic iron	16.78	16.73	11.56	13.19
Metallic manganese	30.57	30.75	12.21	12.33
Phosphorus	0.19		0.104	

The thickness of the crustal deposits is not known as none is known to have been penetrated by a sampler. The core and Eckman samplers are useless with these deposits, and acquirement of samples had to be done with the Petersen dredge. It is believed that the deposits are not very thick, but it is known that the maximum thickness of crust acquired, just a little less than 7 centimeters, does not represent the entire thickness as this was torn from underlying similar deposits.

Not many occurrences of manganese and iron like those in Trout Lake have been described, and this is believed to be the first described from Wisconsin. Many bog deposits of the two metals have been described. Deposition in Trout Lake seems to be in progress, and it probably has been in progress for a very long time. The quantity present does not seem commensurate with the small quantities of the two metals in the waters of the lake.

The maximum depth from which crustal deposits of the two metals have been obtained is 26 meters (86 feet), and the range in depth from which such deposits have been obtained is from about 7 to 26 meters (23 to 86 feet). The deposits bear no apparent relations to places of entrance of streams. Some places of occurrence are close to shore, but very shallow depths are lacking in deposits other than thin coatings of the two metals on sands and larger particles in a few places. No deposits of the metals were found in deep holes of the bottom.

In general, all deposits are in hypolimnium waters of the lake where, except at the times of the semiannual overturns of the waters, there is an abundance of carbon dioxide and oxygen is rare or wanting. Under these conditions it is difficult to understand how oxides of the two metals could be precipitated from solution. Deposition as carbonates would seem more probable.

STRATIFICATION OF SEDIMENTS IN TROUT LAKE

All deposits of sands observed in Trout Lake are stratified, but no sample of gyttja showing stratification was seen. Naturally, all evidence of stratification would be destroyed in gyttja collected with the Eckman dredge, but stratification should have been preserved in samples acquired with the Jenkin and Mortimer core sampler.

As absence of stratification has been found in every deposit of gyttja in all lakes studied it is concluded that it probably is a general rule. The absence of stratification is referred to the slowness of deposition which permits organisms dwelling in the gyttja repeatedly to work the sediments over so that the deposits of any one time are mingled rather thoroughly with the sediments previously deposited. It is possible that some stratification may develop on compaction during which a thickness of gyttja of 10 to 20 feet would be reduced to about a foot, and thus differences in the characters of the sediments at the base of 10 to 20 feet and those at the top of that thickness would become obvious.

RATE OF DEPOSITION AND DIAGENESIS OF THE GYTTJA

The greatest thickness of gyttja found in Trout Lake was 4.8 meters or about 19 feet. After expulsion of water and compaction this would become reduced to about 0.5 meter or 1.6 feet. It is not known that 4.8 meters is the total thickness, but it is believed that it is near it. If the Wisconsin glacier departed from the Trout Lake region about 25,000 years ago, the very slow rate of deposition of about 1 foot in 15,000 years is obtained.

There is little evidence of much change in the character of the sediments deposited in Trout Lake since the beginning of deposition. The gyttja shows that a little water has been expelled, but there has been little compaction and little modification of composition. It seems obvious that diagenetic processes are not proceeding very rapidly.

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ABSTRACTS

These abstracts represent papers delivered orally or by title before the December 1945 meetings of the Mineralogical Society of America, Society of Economic Geologists, the Paleontological Society, Society of Vertebrate Paleontologists, and The Geological Society of America, held at Pittsburgh, Pennsylvania.

For easier reference the abstracts are not segregated according to societies but are listed alphabetically by authors. In the programs for the meetings those papers presented orally are grouped according to subject.

CROWN POLISHED ROCKS OF TRANS PECOS TEXAS

JOHN EMERY ADAMS

The theory of natural sand blasting by dust eddies, advanced to explain crown polished rocks in semiarid Trans-Pecos Texas, is abandoned in favor of Indian polishing. Polish is limited to the upper surfaces or crowns of large rounded boulders and isolated pinnacles. Most polished boulders are igneous rocks between 5 and 10 feet high. At present the polish is decaying rather than developing. Surfaces of depressions and grooves sinking below the rounded outlines of the rock mass are unpolished. Magnification of smoothed mineral faces show fine criss-crossing scratches as though the rock had been ground away with emery cloth.

Early settlers say that boulder localities mark old Indian campsites, remains of which can frequently be found. During skin-dressing processes, hides thrown over the crowns of the rocks were pulled back and forth by squaws until dry and soft. The same campsites and boulders were used by generations of squaws. Sand and dust adhering to the hides ground away the rock surfaces and polished them to their present smoothness.

This explanation accounts for (1) localization of polished boulders in scattered groups; (2) type of grinding and polishing action suggested by fine surface markings; (3) limitation of polishing to crown surfaces; (4) absence of polish in protected depressions; (5) selection of originally rounded boulders for polishing; (6) absence of current polishing.

GEOLOGY OF THE SAN JUAN BAUTISTA QUADRANGLE, CALIFORNIA

JOHN ELIOT ALLEN

The San Andreas fault and the Pajaro River separate the two stratigraphic and physiographic provinces of the extreme southern Santa Cruz and northern Gabilan ranges in the central Coast Ranges of California. Of 18 units mapped, 7 appear in the Santa Cruz Range only, 6 appear in the Gabilan Range only, and 5 appear in both provinces.

In the Gabilan Range the oldest rocks are the Sur series of quartzites, schists, and Gabilan limestones, intruded by Santa Lucia granitics. San Lorenzo shales and sandstones lie upon the granite, followed by Vaqueros sandstones and red beds, and by lava flows and agglomerates and interbedded sandstones. The Tertiary rocks are separated from the granite on the south by the east-trending Vergeles thrust and are further broken by parallel thrusts and numerous cross faults.

The Santa Cruz Range is divided by two longitudinal faults which parallel the San Andreas fault. In the northeast belt Franciscan basaltic tuffs and agglomerates are overlain by basalt flows and by sandstones and shales which include limestone and black chert lenses near the base and red chert lenses near the center of the section. Serpentines appear as "cold intrusions" along boundary faults of the Franciscan belt. The Monterey belt is composed of arkosic sandstones and clay shales overlain by highly folded diatomaceous and siliceous shales. Purisima and later gravels, sands, and silts unconformably overlie older rocks of both provinces and are unconformably overlain by Aromas (Pleistocene) red sands and by terrace gravels, alluvial fans, and valley alluvium.

NONTRONITE IN THE PACIFIC NORTHWEST*

VICTOR T. ALLEN AND VERNON E. SCHEID

Several new occurrences of nontronite have been discovered in Washington, Idaho, and Oregon during the investigation of high-alumina clay by the Geological Survey, U. S. Department of the Interior. The nontronite forms from basaltic glass, palagonite, iddingsite, and augite under conditions of poor drainage in the presence of alkalies or alkaline earths, especially magnesium. Under conditions of thorough drainage in the presence of neutral or slightly acid solutions kaolinite and halloysite form from plagioclase feldspar while nontronite migrates and fills vesicles as well as cracks ranging from a fraction of an inch to 6 inches in width. From large veins near Spokane, Colfax, and Garfield, Washington, three new nontronites have been analyzed, and their optical properties and geologic relationships have been determined.

ICE AGE AND THE PLEISTOCENE IN CALIFORNIA

ERNST ANTEVS

The first Quaternary glaciation in the Sierra Nevada, the McGee-Glacier Point, postulated that the range had then almost attained its modern height (Matthes). The last uptilting of the Sierra fault block may have been associated with the downwarping, in southern San Joaquin Valley, of the Tulare formation which, formed above the sea, now reaches 1000 to 2500 feet below sea level, as revealed by well records. This downtilting may also have been connected with the folding of the Tulare on the west side of the valley, *i.e.* with the last climax of the Coast Range, or Pasadenan, orogeny. Since this probably occurred about the Mid-Pleistocene, and since deposition of the marine Pleistocene, the last Pasadenan diastrophism, and the later geologic history seem to require about twice as long as does the Ice Age, two lines of evidence suggesting correlation which implies the following succession of events: (1) deposition of the marine Early Pleistocene of southern California and peneplanation in the Sierra Nevada (mountain-valley, Chagoopa Plateau); (2) last, Mid-Pleistocene, peak of the Coast Range orogeny and the last rise of the Sierra Nevada which introduced the last canyon cutting; (3) post-orogenic events in southern California and the Ice Age and continued canyon erosion in the Sierra Nevada.

This succession agrees with that advocated by Eaton, but differs notably in detail. The California Pleistocene is believed to be comparatively short, since its base is at the appearance of an essentially modern invertebrate fauna. Each geologic province apparently had its own history, especially in post-orogenic time.

The gulches of Bridalveil and other creeks cannot indicate the approximate level of the preglacial Merced River in the Yosemite region, as Matthes assumes, for this would imply that the canyon at El Portal was lowered only 350 feet during the entire Ice Age, while canyons 2000 feet deep have been eroded on the east flank of the range since the first glaciation (Blackwelder). Apparently the rise of the Sierra Nevada was much faster than canyon cutting. This latter, which began with the preglacial uptilting, is still going on.

The first rise of the modern Sierra Nevada is recorded by a change in vegetation in Nevada from mesic to xeric between the Early Miocene and the Mio-Pliocene transition (Chaney and Axelrod). It seems to be dated by the geological conditions near Bakersfield at the late Upper Miocene.

POSTPLUVIAL CLIMATIC HISTORY OF THE WEST

ERNST ANTEVS

The climatic evolution of the Postpluvial, or the past 10,000 years, in the western United States is gleaned from fluctuations of lakes and glaciers, cutting and filling of channels, wind erosion and

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stabilization of dunes, changes in vegetation (pollen profiles), rate of tree growth, observed rainfall and runoff, and so on. The climate seems to have undergone the following variations:

1945		
A.D. 0	Late Postpluvial	Cool and moist
B.C. 2000		
	Middle Postpluvial	Distinctly warmer and drier than at present
6000		
	Early Postpluvial	At first as today, but growing warmer and drier
8000		

During the Middle Postpluvial most glaciers disappeared (Matthes), arroyos were cut, basins were lowered by wind erosion, and Abert, Summer, and Owens lakes dried, to be reborn some 4000 years ago, judging from their recent salt contents.

Superimposed on the major climatic fluctuations were others of several orders, whose regions are little known. In southeastern Arizona and south-central Oregon the moisture maximum of the Late Postpluvial was reached before the time of Christ. Summer Lake then formed a sand beach at 4190 feet, 12 feet above its highest modern level (Allison). The glaciers attained their greatest extent of the past 10,000 years about 1850 A.D. (Matthes). Low at that time, the Great Basin lakes rose to unusually high levels about 1870 because of increased runoff, associated with the retreat of the glaciers.

The modern age is climatically unstable. Most glaciers throughout the world attained their postglacial maxima between 1600 and 1875 A.D. and have since been reduced. The temperature is rising in the United States since about 1850. Modern channel erosion might be caused in part by drought, not exclusively by overgrazing. Bryan ascribed it to progressive drought. The drought of 1924–1934 was in the Lapine region, Oregon, the severest in over 650 years. Are we entering a warmer and possibly drier age?

POSSIBLE EXTENSION OF THE LEVIS TROUGH INTO PENNSYLVANIA

GEO. H. ASHLEY

In eastern New York and the St. Lawrence Valley, three troughs, or possibly one deep trough, carry Cambro-Ordovician sediments. The central or Levis trough, or deep center of a single trough is characterized by thick (up to 6,000 feet) dark or black graptolite shales and lacks the limestones and other beds characteristic of the areas either side. These dark shales, formerly "Hudson River shales", extend in age from Middle Cincinnati (Pulaski) to Beekmantown or Ozark.

The presence in Pennsylvania of graptolite shales with characteristic Normanskill (Chazy) and Deepkill (Beekmantown) graptolites and lenses of limestone of apparently Beekmantown or Ozark age clearly inclosed in so-called "Martinsburg" shale, supposed to extend down only to middle Trenton, suggests that the hypothetical "deep", known in the Hudson River and St. Lawrence valleys, extended to Harrisburg. If true, this may answer many questions in doubt for 30 years or more. The idea is strengthened by the unusual thickness of the shales (estimated 5000 feet by Behre) and the crustal trench revealed by recent gravity studies.

PLACER DEPOSITS OF RESIDUAL MARCASITE ON THE WEST SHORE OF LAKE MICHIGAN

JOHN R. BALL

Schoolcraft (1820) reported crystals and nodules of pyrite on the west shore of Lake Michigan, 20 miles south of the mouth of the Milwaukee River. Schoolcraft's party encamped that night about 35 miles south of Milwaukee and that is where his map locates the "Beds of Pyrites."

Since 1914 the author has made other locations of these deposits. They are placers of marcasite nodules, chiefly, although pyrite is associated. The average size of the beach nodules ranges from that of a pea up to about 45 mm. across. The largest fragment obtained weighs 4 pounds.

Some of the beach placers are located less than a mile north of Wind Point, Wisconsin; a mile south of the south limits of Racine; 5 miles and 2½ miles north of the Kenosha Harbor; and about half a mile north of the pumping station, Glencoe, Illinois. This report shows residual marcasite deposits for approximately 60 miles along the shore. Greater distances of distribution probably will be recorded.

The efficiency of lake waters in transporting the shore material, the probable sources of the marcasite in bedrock formations, a list of fossils replaced by marcasite, and the aid of the U. S. Lake Survey charts in locating rock in the bed of Lake Michigan are considered in the paper.

ARTIFICIAL RECHARGE OF PRODUCTIVE GROUND-WATER AQUIFERS IN NEW JERSEY*

HENRY C. BARKSDALE AND GEORGE D. DEBUCHANANNE

Artificial recharge by water spreading is practiced in several places in New Jersey. Rates of recharge ranging from 4000 to 90,000 gallons per acre per day have been measured at the Perth Amboy Water Works, where artificial recharge of the Old Bridge sand, of upper Cretaceous age, has been practiced for more than 30 years. At the Duhernal development, which also draws from the Old Bridge sand, more than 4,000,000 gallons daily is now derived from artificial recharge. This rate will probably increase with further lowering of the water table near the lake. For many years the Princeton Water Company has pumped water from a stream for recharging the Stockton sandstone, of Triassic age. The City of East Orange spreads the water from several small streams over parts of the intake area of the Quaternary beds supplying its wells. The estimated total recharge is about 1,000,000 gallons daily. Closely related to artificial recharge are those instances wherein well sites are chosen to take advantage of potential recharge from existing bodies of surface water. At the Borough of Manville no water-spreading operations are conducted, but about 80 per cent of the water from its wells is derived by recharge from the Raritan River.

STRATIGRAPHY AND STRUCTURE OF NORTHEASTERN ILLINOIS†

CARL A. BAYS, ERNEST P. DUBOIS, STEWART H. FOLK, PAUL HERBERT, JR., LELAND HORBERG, CHARLES G. JOHNSON, AND ROBERT R. STORM

A regional study of Kankakee, Will, Cook, DuPage, Lake, Kane, and parts of Boone, McHenry, and DeKalb counties, Illinois, has emphasized the geological factors controlling ground-water supply and resources in the Joliet region. All important wells were studied, and both well samples and outcrop samples were analyzed by microscopic examinations, insoluble-residue determinations, size analyses, and heavy accessory-mineral studies.

Strata of only the Ordovician, Silurian, Pennsylvanian, and Pleistocene systems crop out, but extensive well data permit detailed description of the older beds as well. The oldest sedimentary strata above the pre-Cambrian basement rocks are red clastic strata classified as pre-Cambrian (?) and tentatively referred to the Fond du Lac formation. Cambrian formations recognized are the Mt. Simon, Eau Claire, Galesville, Franconia, and Trempealeau, in ascending order. Most of the Lower Ordovician strata are assigned to the Oneota formation, but in the southern portion of the area the New Richmond sandstone and Shakopee formation are present. The St. Peter sandstone was deposited over a very irregular, mature, solution surface which lies on all formations from the Franconia to the Shakopee. The Platteville-Galena formations and the Maquoketa formation are present throughout the area. The Alexandrian and Niagaran strata constitute the surface bedrock through most of the region, although the Pennsylvanian overlaps the Niagaran in the southwestern portions of the area.

The Pleistocene deposits in the vicinity of Joliet are described, and the pre-glacial drainage system is delineated.

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Regional dip is east and southeast. A series of nearly parallel low-relief anticlines and synclines cross the area and plunge southeast. In the region of DesPlaines, Cook County, a disturbed area of about 25 square miles has strata from Lower Ordovician to Kinderhook in age at the bedrock surface under the glacial drift. The area has very complex faulting and is considered as a probable "crypto-volcanic" structure.

RECONNAISSANCE OF THE GEOLOGY AND OIL POSSIBILITIES OF LOWER CALIFORNIA, MEXICO

CARL H. BEAL

Baja California is about the same length (1300 km.) as California but has only a little more than one-third the area. Essentially it is a westward-tilted fault block, with its mountainous northern half consisting mainly of crystalline rocks, which rise to elevations of more than 10,000 feet. Most of its southern half is a great area of volcanic flows and detrital rocks, overlying crystalline rocks and unaltered Tertiary marine sediments of pre-Upper Miocene age.

The formations exposed are the partly metamorphosed Lower and early (?) Upper Cretaceous San Fernando formation, unconformably overlain by the unaltered Upper Cretaceous Rosario formation; the Tepetate formation of Paleocene to Eocene age; unnamed beds of probable Oligocene age; the San Gregorio formation, Oligocene (?) to Lower (?) Miocene in age; the Ysidro formation, assigned to the late Lower or Middle Miocene, or both; the Comondú formation, a series of volcanic rocks of Upper Miocene (?) age; and the Salada formation of Pliocene age.

Structurally, the peninsula is considered part of a single diastrophic unit extending southeastward from the latitude of Los Angeles, California, bounded on the east by a great structural depression which includes the Salton Basin in southeastern California and the Gulf of California, and on the west by the continental slope fault.

Tests for oil so far drilled on and adjacent to the peninsula have been dry holes. Three basins of deposition on the west slope of the peninsula may be attractive for future prospecting: the region north and east of Bahia de Magdalena, Desierto de Santa Clara, and near the 30th parallel, respectively.

GLACIAL DRIFT ON EAST BOULDER PLATEAU, BEARTOOTH MOUNTAINS, MONTANA

ARTHUR BEVAN

East Boulder Plateau is a slightly dissected large remnant of the subsummit plateau which constitutes the uppermost part of the Beartooth Range south of the plainsward front in southern Sweet Grass County, Montana. It is situated just east of the deep glaciated canyon of the main Boulder River and northwest of the similar canyon of the upper part of the West Fork of Stillwater River. It slopes gently northward from an altitude of 9500 feet to about 9000 feet in a distance of 8 miles.

A reconnaissance trip across the plateau in 1945 resulted in the recognition of two high-level glacial drifts: an older one in the shallow valley of East Boulder River atop the plateau and on the slightly higher bordering upland; and a younger one spread fanwise over the southeastern end of the plateau. Numerous subangular to subround granitic boulders to a maximum known diameter of 10 feet lie half buried upon pre-Cambrian quartzites and schists. Some boulders of basic igneous and metamorphic rocks are distinctly soled and striated.

The granitic erratics were derived apparently from the far (south) side of the 1500-foot canyon of the West Fork of Stillwater River. Both drifts appear to be of Pleistocene age. Detailed field work will be necessary to prove or disprove tentative interpretations. (Geological Society project.)

SOURCES OF YELLOWSTONE GLACIERS NORTH OF YELLOWSTONE NATIONAL PARK

ARTHUR BEVAN

General reconnaissance geomorphic studies have recently been made of parts of the Beartooth and Absaroka mountains directly north of Yellowstone National Park. It is tentatively concluded that

glaciers of large volume originated along the south side of the high alpine divide which extends, with only a single important gap, from Stillwater canyon north of Cooke City, Montana, toward Yellowstone Valley north of Gardiner. The glaciers included long, broad valley glaciers, possibly a continuous ice-cap connection with the Rainbow ice cap on Lake Plateau to the north, and deployment to the south perhaps, in part at least, as a piedmont glacier. The forms, sizes, extent, and general relations of these Beartooth-Absaroka glaciers to the mass of ice on Yellowstone plateau in the Park remain to be deciphered by detailed field studies. (Geological Society project.)

NEW COLORED GEOLOGICAL MAPS OF THE MT. WASHINGTON, BELLOWS FALLS, AND PLYMOUTH QUADRANGLES, NEW HAMPSHIRE

MARLAND P. BILLINGS

New colored geological maps of three quadrangles in New Hampshire have been printed for the New Hampshire State Planning and Development Commission. These maps will be issued soon.

The field work for the Mt. Washington quadrangle was done by M. P. Billings, C. A. Chapman, R. W. Chapman, K. Fowler-Billings, and F. B. Loomis, Jr. between 1936 and 1940. This quadrangle, which contains the highest peaks in the northern part of the Appalachian Mountains and has a total relief exceeding 5000 feet, displays three major structural types: (1) folded high-grade metamorphic rocks of Ordovician (?) and Devonian age; (2) a great dome composed of lenses of concordantly injected granitic rocks of middle Devonian (?) age; and (3) Mississippian (?) stocks and ring-dikes.

The field work for the Plymouth quadrangle was done by Charles B. Moke between 1935 and 1937. This quadrangle is underlain by three groups of rocks: (1) folded high-grade Devonian schists; (2) plutonic rocks of late Devonian (?) age; and (3) stocks of syenite and granite of Mississippian (?) age.

The field work for the Bellows Falls quadrangle was done by F. C. Kruger between 1937 and 1940. The strata of this quadrangle, ranging from Ordovician (?) to Devonian, show all gradations from low-grade to high-grade metamorphic rocks. The plutonic rocks occur as thick, concordant sheets. In recent years considerable mica and feldspar have been produced from the pegmatites in this quadrangle.

RADIOACTIVITY OF FOUR PALEOZOIC MAGMA SERIES IN NEW HAMPSHIRE

MARLAND P. BILLINGS AND NORMAN B. KEEVIL

The Ordovician (?), Silurian, and Devonian strata of New Hampshire are intruded by igneous rocks belonging to four magma series, the oldest of which is late Ordovician (?), the youngest of which is Mississippian (?). Each magma series consists of rocks ranging from gabbro, diorite, or quartz diorite to granite.

Although individual specimens from a rock type within a single magma series commonly show considerable range in radioactivity, the average values show a progressive increase toward the granitic end of the series, which is three to four times as active as the gabbro-diorite end of the series. The reason for this increase in radioactivity toward the granitic end of the series is not always clear, but in the White Mountain magma series it appears to be due to an increase in the amount of allanite and probably zircon. This magma series is twice as radioactive as the other magma series in New Hampshire, and considerably more radioactive than similar rocks in most other parts of North America. It is suggested that the parental basaltic magma from which the White Mountain magma series was differentiated was more radioactive than the primary magmas from which the older magma series were derived.

GLACIATION IN THE SOUTHERN PART OF THE WIND RIVER MOUNTAINS AND THEIR FOOTHILLS

E. B. BRANSON AND C. C. BRANSON

On Wind River Peak near the south end of the Wind River Mountains two small glaciers are still extant. Between Wind River Peak and Fremont Peak, about 40 miles northward, there are several

small glaciers. In the foothills 8 miles south of Lander a small glacier originated at an elevation of about 8000 feet and advanced for less than 2 miles. Well-defined terminal and ground moraines were left by it.

CONODONTS FROM THE BRASSFIELD FORMATION OF KENTUCKY

E. B. BRANSON AND C. C. BRANSON

The junior author collected conodonts from several Brassfield localities in Kentucky in 1941 and 1942. Some species are transitional from Upper Ordovician to Middle Silurian, and some new genera appear, one of which is the most diagnostic of all the Lower Silurian forms.

UPPER TRIASSIC AND OVERLYING FORMATIONS IN CENTRAL WYOMING

E. B. BRANSON AND C. C. BRANSON

The contact of the Upper Triassic and overlying formations was discussed by us in the 1933 meeting of this Society, but the paper was not published. Several years of investigations have enabled us to add new information. The unconformity at the contact is well exposed. The fossils of the uppermost Triassic are indefinite, but the changes in fossils from Triassic to Jurassic are pronounced. In the uppermost Triassic, Gypsum Springs, in the region east of the Wind River Mountains one member is largely made up of algae, one member contains many small gastropods, and one member contains many small pelecypods. None of these is diagnostic. The echinoids reported from the Gypsum Springs have not been found by the authors, but echinoids are common in the basal Sundance.

DISTRIBUTION OF CONODONTS IN THE RICHMOND OF KENTUCKY

E. B. BRANSON, M. G. MEHL, AND C. C. BRANSON

Studies of conodonts from the Arnheim, Waynesville, Liberty, Saluda, and Whitewater of Kentucky, collected by the junior author, add one genus of distacods and three genera of complex forms to the known conodonts. Several new species of well-known genera are also listed.

The collections are sufficiently extensive to give meaning to the stratigraphic distribution of old and new species in the Upper Ordovician in a distribution chart to be presented with the paper.

ARTIFICIAL RECHARGE OF GROUND-WATER ON LONG ISLAND, NEW YORK*

M. L. BRASHEARS, JR.

In 1933, the water table in a large area in western Long Island was below sea level, and potability of ground water was threatened by inflow of sea water. To prevent further overdevelopment, the New York State Water Power and Control Commission has required that water pumped from new wells for cooling and similar purposes be returned to the ground. During the summer of 1944, over 200 recharge wells and several recharge pits were returning water at the combined rate of about 60,000,000 gallons a day. Also in operation were several large recharge pits which return storm sewer runoff in Nassau County. The water is returned to glacial beds from which most of it is pumped, but in places it percolates into the underlying Cretaceous formations. Well drillers have developed recharge wells capable of returning as much as 1000 gallons a minute, many of them having been in operation for over 5 years without failing. Recharge pits dug in coarse glacial gravels are capable of returning about 1,000,000 gallons a day per acre of exposed surface. The legal requirement that water pumped for cooling be returned to the aquifer has caused a gradual decrease in net withdrawal of ground water but has increased actual use. Hence a rise in water levels has occurred in the critically overdeveloped area. Water levels reached lowest stage at the end of 1941 and have recovered slowly since then. However, water levels are still far below sea level in many places, and sea water continues to move inland in areas of heavy pumping.

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STRUCTURAL CONTROL OF ORE BODIES IN THE JEFFERSON CITY, TENNESSEE, AREA*

ARNOLD L. BROKAW AND CHARLES L. JONES

The zinc deposits of the Jefferson City area are confined to the lower half of the Kingsport formation of the Knox group of rocks. They are on the southeast flank of a northeast-trending anticline which is partially overridden from the southeast by the Bays Mountain thrust sheet. The beds show low dips. The area is transected by a series of high-angle strike-slip faults having relatively small displacement and striking essentially parallel to the dominant northeast structure. Minor cross folds transverse to the regional structure are numerous. Three sets of fractures trending N. 45–50° W., N. 30–40° E., and N. 60–70° E. are well developed.

The ore bodies are irregular but generally have a distinct elongation. The vertical extent may be limited to a single bed or may include several beds, depending upon local structure. All ore bodies are confined to zones of pre-mineral deformation. The linear trends of the ore bodies show a remarkable parallelism to the axes of the cross folds. Ore occurs on any part of the flexures, but maximum concentration is on the anticlinal crests and synclinal troughs; the ore attains greatest thickness on the anticlines. Fractures associated with the folding exhibit local ore control. Faults are poor sites for ore, but fracturing and drag folding accompanying faulting produce conditions favorable to ore deposition.

ARTIFICIAL METAMORPHISM OF MINERALS

M. J. BUERGER

Metamorphic textures imply grain growth. Theoretically, this can be experimentally produced by heating a mineral aggregate containing grains of high energy. Such grains can be provided by plastic deformation. Guided by this theory, many monomineralic aggregates have been experimentally metamorphosed by treating them in the following steps: (1) The aggregate is first plastically deformed by application of intense pressures, (2) the deformed aggregate is heated above a certain critical temperature. Above this temperature, which varies with the crystal species, the aggregate recrystallizes. The grain size increases with the time and temperature of heat treatment. The whole process has been followed by x-ray studies, which demonstrate the reality of strain in the plastically deformed aggregate, followed by release of strain and grain growth in the heated aggregate.

UNIT CELL AND SPACE GROUP OF PYRRHOTITE

M. J. BUERGER

The crystal structure of cubanite, which has been recently solved, is unlike the accepted structure of pyrrhotite, which it ought to resemble. This suggested that the accepted structure of pyrrhotite might be in error. To study this, pyrrhotite crystals from several localities have been examined by the precession method. This demonstrated that at least the accepted cell of pyrrhotite is in error. The dimensions of the cell of Schneeberg pyrrhotite are:

$$a = 6.87 \text{ kX}$$
$$c = 22.70$$

This cell has twice the a axis, four times the c axis, and eight times the volume of the nickel-arsenide type structure accepted for pyrrhotite. The diffraction symbol of pyrrhotite is 6/mmmC-/--- This includes the space groups C6/mmm, C62, C6mm and C$\bar{6}$m2.

CARBONIFEROUS AND MESOZOIC ROCKS OF BIG COTTONWOOD CANYON, UTAH*

F. C. CALKINS

J. Stewart Williams, in the G.S.A. Bulletin for April 1, 1943, has misinterpreted the stratigraphy of certain formations exposed in Big Cottonwood Canyon, southeast of Salt Lake City. In the

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section on pages 600–602, "Weber" should be "Nugget". The rocks called "Morgan" comprise the Ankareh as defined by Boutwell, the Thaynes, and the Woodside. The "Brazer" includes the Park City and part of the Weber, and the "Madison" includes the Deseret as well as the Madison proper.

Plate 2 could be partly corrected by changing "Є" to "MM", "MM" to "MB", and "MB" to "PW". "PM" is at the foot of a cliff of Thaynes rocks, underlain by Woodside shale. Park City formation is exposed in the deepest saddle on the skyline, and the overthrust, which crosses a little to the right of the saddle, is overlain successively by rocks of Brazer and Morgan (?) age, and by the Weber quartzite. The overthrust does not branch as shown, but a minor thrust parallel to it crosses the skyline above "PM".

The main overthrust, which might be called the Mill A overthrust, is cut off near Dog Lake by the Silver Fork fault, which here has a downthrow on the east of about 2000 feet. Doctor Williams' error may have been caused in part by failure to recognize this fault.

INTERNAL STRUCTURE OF GRANITIC PEGMATITES*

E. N. CAMERON, R. H. JAHNS, A. H. MCNAIR, AND L. R. PAGE

It has long been recognized that many pegmatite bodies are divisible into lithologic and structural units of contrasting composition or texture, but no classification of these units applicable to large groups of pegmatites has appeared. Recent investigations of pegmatite-mineral deposits by the Federal Survey during a period of unusually widespread mining operations gave an exceptional opportunity for detailed structural analysis of pegmatite bodies. Some forty geologists were engaged in this work, chiefly in South Dakota, Colorado, Wyoming, Idaho, New Mexico, the Southeastern States, and New England. Comparisons of findings indicate that certain types of lithologic and structural units are common in pegmatites studied in all districts. The various types will be described and illustrated, and a general classification of pegmatite units will be discussed.

CAMBRIAN ROCKS OF NORTHEASTERN STEVENS COUNTY, WASHINGTON

C. D. CAMPBELL

Most of the marine metasedimentary rocks of the Northport mining district are tentatively correlated with three of the Cambrian formations established by Park and Cannon in the Metaline quadrangle, immediately east. Of the established Cambrian succession, the formations of the Northport district include the Metaline limestone, Maitlen phyllite, and the upper half of the Gypsy quartzite. Contacts are gradational. Fossils are scarce, and most of the correlations are based on similarities of lithologic sequences.

The Metaline limestone appears to be over 6000 feet thick and underlies the Ordovician Ledbetter slate with little or no angular unconformity. The brachiopods *Nisusia* sp. and *Acrotreta* sp. were found near the middle of the formation on Gladstone Mountain. They indicate, according to Bridge, an early Middle Cambrian age, as do the trilobites found at a lower horizon in the Metaline district.

The upper third of the formation is fine-grained light-gray calcite and dolomite marbles locally altered to jasperoid and nonbedded dolomite. The central third is principally bedded white sugary dolomite marble containing many beds of dark- and medium-gray dolomite; tremolite or jasperoid and nonbedded dolomite have formed along major shear zones. The basal third consists of alternations of dark-gray limestone and phyllite beds.

The Maitlen phyllite, over 3700 feet thick, includes black, gray, and green phyllites. Several beds of marble and one of quartzite occur near the top.

The Gypsy quartzite includes arkosic and micaceous types.

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NESTED FOLDS

GEORGE HALCOTT CHADWICK

Superposed (not superimposed) anticlines and superposed synclines in the Helderbergian and Silurian limestones of the Kalk Berg range west of Catskill, New York, have resulted from the subsequent folding of slices of these limestones that had been imbricated while the beds were still horizontal. Both the imbrication and the later simultaneous folding of beds and thrust planes are referred to the prolonged Acadian orogeny but are thought to have occurred under respectively a lesser and a greater overload of the rapidly thickening deposits of the so-called Catskill red-beds delta or coastal plain. Strata as late as the Middle Devonian (Onondaga limestone) are involved. The first compression may be post-Hamilton (with 4000 feet of overload), the second one post-Chemung (with 10,000? feet of overload).

MORAINE ON MOUNT DESERT ISLAND

GEORGE H. CHADWICK

Mount Desert Island, Maine, is crossed by a triple moraine extending from Bartlett's Island on the northwest, south of the dorr lakes (of which it usually forms the dam) to disappear northeast into Frenchman's Bay. In its eastern half, this moraine is fronted by marine deltas showing water level to present 240 feet A.T. Older ocean levels up to 290 feet A.T. are indicated south of it, while later channels and deltas farther north demonstrate progressive emergence during recession. This moraine is thought to mark a considerable oscillation in the ice front.

LINEAR ANALYSIS OF A MEDIUM-GRAINED GRANITE*

FELIX CHAYES

The design and results of an experimental evaluation of the precision of linear analysis are described. The most probable values given by linear analyses do not vary significantly with variation of the traverse interval, providing the entire slide is traversed. The precision both of a single linear analysis and of a mean based on a group of analyses varies inversely with traversing interval. The mean of a large number of linear analyses will not differ from a true Rosiwal analysis of the same group of slides.

Numerical statements of these conclusions are given for the Woodstock, Maryland, granite as analyzed by the writer on the Hurlbut and Wentworth-Hunt micrometers. It is shown by comparison of Hurlbut- and Wentworth-stage results that the precision of the latter is of the same order as that of the former.

It is suggested that granites of different origins may be characterized by nonsymmetrical or not directly observable differences in the thoroughness with which their constituents are mixed. Such differences could be described in terms of the variance exhibited by small surfaces; accumulation of data for variance studies would proceed in a fashion very similar to that described here.

STANDARD SECTION FOR THE PRE-CURDSVILLE MIDDLE ORDOVICIAN

BYRON N. COOPER

In the southern Appalachian region, beds known certainly to be linked with the New York Chazy are limited to the Lenoir limestone and its clastic equivalent, the Blackford formation. All the other pre-Curdsville Middle Ordovician formations have strong faunal affinities either with the Black River or with the lower Trenton. Possibly beds as young as the Lincolnshire limestone may be correlative to the Valcour, but the dominant elements of the Lincolnshire fauna are unknown in the Chazy. The base of the Black River has been drawn too high in previous correlations. Bonafide

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Black River fossils occur hundreds of feet below limestones identified by Ulrich and Butts as Lowville and by Kay as the Pamelia equivalent. These supposed Lowville or Pamelia beds are no older than late Black River and possibly are as young as early Trenton.

Taken together, the Chazy and Black River groups do not represent so full a record of pre-Curdsville Middle Ordovician time as the succession in the southern Appalachian region. Confusion has resulted from attempts to fit all the thick and varied Middle Ordovician of the Appalachian region into the Middle Ordovician groups of New York. It is suggested that the proposed Appalachian section now be considered the standard for pre-Curdsville Middle Ordovician correlations in the eastern United States.

CONODONT ASSEMBLAGE FROM THE LOWER KINDERHOOK BLACK SHALES

CHALMER L. COOPER

Conodont assemblages, first reported by Hermann Schmidt in 1933, have been described by subsequent writers from black fissile shales of Pennsylvanian to Middle Mississippian ages. The assemblage described is from the top of the black shale, from an outcrop on the south flank of the Cincinnati arch, in eastern Lincoln County, Kentucky. Since it was collected just below the concretion zone in the Linietta clay, it is considered to be at the horizon of the Sunbury shale of Ohio. Five pairs of denticulated bars are recognized, with one complete *Hibbardella* unpaired. There are no polygnathids present.

MICROFAUNAS OF PENNSYLVANIAN-MISSISSIPPIAN BORDERLINE FORMATIONS*

CHALMER L. COOPER

The microfaunas described from the youngest Mississippian beds in the Mississippi Valley and the oldest Pennsylvanian beds in the Morrow of Oklahoma and Arkansas are predominantly ostracodes. Next in abundance are the Foraminifera, with conodonts and Bryozoa following in order. The most interesting aspect of the faunas is in the occurrence of several species of Morrow ostracodes in the uppermost Kinkaid zones, where the primitive fusuline *Millerella* also is found.

ORIENTATION ANALYSIS OF FINE-GRAINED CLASTIC SEDIMENTS

E. C. DAPPLES AND J. F. ROMINGER

Using laboratory material, this investigation has been directed toward the extension of methods of orientation analysis to fine-grained clastic sediments to determine their last depositional environment and direction of movement of the depositing agent. Two measurements are made on the projections of grains exposed on the bedding plane: (1) azimuth of elongation, and (2) end position (defined as the position of the larger end of the grain with respect to the smaller end). Grain elongation is measured by constructing two parallel tangents to the grain projection and separated by a minimum distance. End position is determined by construction of the least-projection rectangle (least-projection tangents to the grain projection and the perpendicular pair of tangents). The end of the grain having the greater area may then be determined by visual inspection.

Following are the results of the experiments:

(1) For sand deposited by running water the grains are elongate parallel to the current direction with their larger end upstream.
(2) For sand deposited by wind action the grains are elongate both parallel to and perpendicular to the current direction, and have their larger end upstream.
(3) Grains rolled down a slope equal to the angle of repose of dry sand show a random distribution of elongation azimuth.

Should work in the field bear out the laboratory findings, the projection method furnishes a means of determining depositional environments and a quantitative measure of current direction prevalent

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during the deposition. Such information should prove of importance in determining the sources of petroliferous sediments, in tracing stratigraphic horizons, and in the construction of paleogeographic maps.

CRATER MOUND, ARIZONA

N. H. DARTON

My geological map of Arizona was recently reprinted with repetition of the name Crater Mound for the wonderful rock upburst about 20 miles west of Winslow. This name which has been established officially by the U. S. Board of Geographic Names since 1932 was used and reused in my *Résumé of Arizona geology*, Guide Book of geology along Santa Fe Railroad (U.S.G.S. Bull. 613) and geologic, and topographic maps of Arizona. The words "Meteor Crater" are not admissible. I am convinced that no meteorite is present, a matter which I discussed in a paper on *Explosion craters* printed in Scientific Monthly in 1916. Extensive shafting and drilling have given entirely negative results as to the presence of buried meteoric iron, and a geophysical survey verified the magnetic tests made for Gilbert. I submitted a plat of this survey (in A.I.M.E.) to one of our most eminent geologists, and he stated that it proved the absence of a meteorite. My present hope for Crater Mound is to have it made a national monument. To anyone interested in such craters I advise a visit to closely comparable Zuni Salt Lake in western New Mexico. It has an encircling rim of fragments ejected from great depth as in Crater Mound but has a volcanic cinder cone in the center of its bottom proving volcanic eruption at the end.

CAMBRIAN GRAPTOLITES FROM TENNESSEE

CHARLES E. DECKER

The writer has made 100 enlarged camera-lucida drawings of Cambrian graptolites from the Maynardsville limestone member of the Nolichucky shale from the Tecoy quarry 7½ miles northwest of Knoxville. There are 7 genera, 2 of which belong to Hydrozoa, 26 species, 9 of which are new, 2 varieties, some brachiopods, and a crustacean.

The species will be illustrated and described and their relations to other Cambrian graptolites noted, especially those from the Wilberns formation of Texas to which they seem most closely related. Also the relations of the various genera will be considered.

CAMBRIAN GRAPTOLITES OF VIRGINIA

CHARLES E. DECKER

The writer has made 122 enlarged camera-lucida drawings of Cambrian graptolites from two zones in the Nolichucky shale about 1½ miles east of Gratton, Virginia. From the lower zone there are 7 genera, two of which belong to the Hydrozoa, 18 species of which two are new, and one variety. From the upper zone there are 4 genera of graptolites, 1 of Hydrozoa, 12 species, 2 of which are new, 2 varieties, and a worm. The species will be illustrated and described and comparisons will be made with Cambrian graptolites of North America, and especially those of Tennessee and Texas to which they are most closely related.

ROCK-COLOR CHART

RONALD K. DEFORD

In the past 2 decades color scientists have built a scientifically sound foundation upon which other scientists may erect simple, usable color standards. Soil scientists have already done so; their standards are usable by field geologists except that the range of rock colors is slightly wider. The preparation of a rock-color chart is advocated.

STRATIGRAPHY AND STRUCTURE OF SLOAN HILL, NEVADA*

CHARLES F. DEISS

Sloan Hill, 19 miles southwest of Las Vegas, Nevada, was mapped by the U. S. Geological Survey in 1943 and 1944. Of the six sedimentary formations exposed, the Valentine limestone and the overlying Crystal Pass limestone are correlated with the Sultan limestone (Devonian) in the Goodsprings quadrangle, Nevada. The Dawn dolomite overlies the Crystal Pass. The Anchor limestone rests on the Dawn and contains lenticular beds and nodules of chert that constitutes 15–20 per cent of the formation. The Bullion dolomite rests on the Anchor and contains one of the high-grade dolomite deposits in western United States. The Dawn, Anchor, and Bullion are correlated with the Monte Cristo limestone (Mississippian) in the Goodsprings quadrangle. The Pennsylvanian Bird Spring formation overlies the Bullion at the north end of the hill.

Sloan Hill is a horst block tilted gently north between two grabens and is bounded on three sides by high-angle normal faults that dip outward away from the horst. The total displacement between the blocks seemingly was distributed along these faults. Two periods of deformation are indicated, an early period of compression (Eocene?) when a few overthrusts and underthrusts were produced, and a later period of tension (Miocene?) when many normal faults developed. The normal faults dip 70° to 80°, are marked by conspicuous breccia zones, and belong to two systems. The first strikes N. 25°–48° W., subparallel to the axis of the hill. The second strikes nearly E.–W. and consists of very short faults.

MICROANALYSIS BY X-RAY DIFFRACTION

J. D. H. DONNAY

Good x-ray powder patterns have been obtained from polycrystalline samples of low-quartz weighing only a few micrograms. The weight of the smallest sample thus identified was about 0.003 or 0.004 milligram.

MARINE EARLY PERMIAN OF THE CENTRAL ANDES AND ITS FUSULINE FAUNAS

CARL O. DUNBAR AND NORMAN D. NEWELL

Late Paleozoic deposits range in thickness from 2000 to over 5000 feet in northern Bolivia and southern Peru. Since the pioneer work of D'Orbigny (1829) they have generally been considered Upper Carboniferous. Fusulines, heretofore unstudied, occur in great abundance at certain horizons over the entire region, and they clearly indicate an early Permian (Wolfcamp) age. Among them are seven species of *Schwagerina*, three of *Pseudoschwagerina*, and five of *Triticites*. The very characteristic Wolfcamp species *Pseudoschwagerina uddeni* Beede and Kniker occurs abundantly in one horizon, and two of the species of *Schwagerina* very closely resemble forms described from Texas. The fusulines thus confirm the inference by Robert E. King (1931), based upon brachiopods, that these deposits of the Lake Titicaca region are Permian rather than Carboniferous.

These late Paleozoic strata rest disconformably on Devonian and are overlapped with profound unconformity by Cretaceous and younger deposits. Although fusulines appear some distance above the base of each carefully studied section, the stratigraphic evidence suggests that in the Lake Titicaca region of southern Peru and Bolivia the entire succession forms a unit of early Permian (Wolfcamp) age.

However, in the region about Tarma in central Peru, there is a thickness of almost 1000 feet of Mid-Pennsylvanian (Des Moines) strata with *Fusulina* and *Chaetetes* resting upon the Devonian. It is succeeded by the Yauli group of red beds and volcanics which is tentatively referred to the Permian.

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STRUCTURAL CONTROL IN THE EASTERN BELT OF THE SWEETWATER BARITE DISTRICT, EAST TENNESSEE*

JOHN C. DUNLAP

This district, near the center of the Appalachian Valley and Ridge Province and 40 miles southwest of Knoxville, consists of three parallel belts of Cambrian and Ordovician sediments separated by major thrust faults, with a barren belt between the eastern and the two western belts. Currently 3400 tons of barite are produced monthly, all from residual deposits.

The deposits are restricted to the Beekmantown division of the Knox dolomite group and occur principally in the limestone member of the lower Kingsport formation; but where structural conditions are favorable, deposits are also found in the Mascot dolomite and limestone above and in the Chepultepec dolomite below. The beds strike N. 50° E. and dip 10–20° SE. Two types of minor structures, causing narrow fractured and brecciated zones, cut across the regional structure and are believed to control the mineralization: (1) "kinks" or sharp flexures caused by abrupt change in strike, and (2) very gentle anticlines. The axes of the minor structures are inadequately known because of few outcrops but probably strike about N. 20° W. with variations from N. 40° W. to W.

Pyrite, fluorite, and barite, listed in order of deposition and increasing abundance, form banded veins in coarse breccia. Traces of sphalerite and galena are found in some of the deposits. Silicification, evidenced by the abnormally large amount of chert in the vicinity of the deposits, is noteworthy.

The barite and associated minerals are believed to have originated from hydrothermal solutions rising through the fractured zones and spreading laterally along favorable beds.

"APPENDAGES" ON CARBONIFEROUS AND PERMIAN BRYOZOA

MAXIM K. ELIAS

The study and revision of genus *Archimedes* provided an opportunity for detailed investigation of the nature of its "supporting" screw and became a starting point for a general research on the encrustations and "appendages" of various late Paleozoic Bryozoa. In 1941 a view was advanced and subsequently developed and elaborated that all these structures have a "phytomorphic" nature and belong to an organism foreign to the Bryozoa, but with which they are more or less intimately associated. The new understanding of the nature and significance of these structures resulted at once in their advanced stratigraphic utilization as index fossils, particularly for Mississippian subsystem and its divisions.

A critical comparative research of fossil and related living Bryozoa, and also of some fossil and living algae, which resemble "appendages" and "supports" of the fossil Bryozoa, seems to substantiate the 1941 conclusion that the phytomorphic structures on many Paleozoic Bryozoa belong to algae. While they have many features in common with various living Red and Brown Algae, they have also some peculiar anatomical details which seem to be unique, may be due to their intimate symbiosis with the Bryozoa, and mark them as a special group of epizoic algae, which seemingly became extinct at or about the end of Paleozoic. However, possibility of their survival into later geologic ages up to the Recent is not entirely excluded.

PROGRESSING PRECISION IN GEOLOGY AND STRATIGRAPHIC PALEONTOLOGY

MAXIM K. ELIAS

The most notable and fundamental progress in present-day geology is not so much an increase in quantity of information which is now available from far away territories, and from previously inaccessible oceanic and subterranean depths, but a finer quality and greater precision of information, which comes from our own and repeatedly explored geologic backyards, and which is economically, as well as scientifically, most important.

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The science of paleontology branched from geology, and progress in paleontology is inseparable from that in stratigraphic geology. The worst and costliest errors by paleontologists are traceable to the lack of co-ordinated work with other paleontologists and stratigraphers in the field and subsequently. Unfortunately, the still-existing scientific isolationism, ignorance of progress in related and neighboring subdivisions of paleontology and geology, overconfidence and belief in own infallibility, absence of self-criticism and intolerance to criticism from elsewhere retard greatly the progress in scientific and economic paleontology and interfere with its adjustment to the ever-progressing precision in modern stratigraphic geology.

Some of the most prominent examples in recent corrections and adjustments of paleontology to stratigraphy are reported and illustrated by lantern slides.

SCOLECODONTS FROM WELL CUTTINGS

E. R. ELLER

Scolecodonts, polychaete annelid jaws, have never been reported formally as occurring in well cores. Examination of well cuttings from the 2859–2938-foot depth of a well at Kawkawlin, Michigan, produced a large number of jaws consisting of many species. More than 100 specimens were recovered from the 2937½-foot depth. Some specimens were as small as 0.09 mm. The well cuttings between the 2865–2938-foot depths are said to belong to the Dundee limestone. Scolecodonts from middle Devonian horizons will be compared with those from the well cuttings for possible correlations. Since scolecodonts are so common in Paleozoic rocks and since they occur where no other fossils are found it is suggested that they may be of value in determining stratigraphy.

SEDIMENT SIZE DISTRIBUTION CODE

K. O. EMERY

Three numbers, median diameter and the coefficients of sorting and skewness, are usually required to express the size distribution of sediments. An alternate method, used in some marine-bottom sediment studies, is proposed for possible wider use. From a mechanical analysis or a microscopic comparison of an unknown sample with a series of mechanically analyzed standards, the weight percentage of grains of each grade size is determined. The grades employed are pebble, coarse sand, medium sand, fine sand, silt, and clay. Wentworth's grade-size limits are used but with some grouping of the sand grades. The size composition of a sediment is expressed by a series of numbers representing in sequence the weight percentages of each of these six grades. For simplicity, the percentage is given as a digit from 0 to 9. Thus the digit 4 means 45 ± 5 per cent. A sample having 14 per cent medium sand, 54 per cent fine sand, and 32 per cent silt would then have the symbol 001530. A decimal is inserted at the 1-millimeter grain diameter limit (between coarse and medium sand) and, if no digit is required for grains coarser than medium sand, a four-digit symbol results. For the example above, the final symbol is 1530. This code permits estimates of the mode, mediam diameter, sorting, and skewness with sufficient accuracy for use in examination of large numbers of samples. Useful results have also been obtained through "contouring" charts on which the symbols were placed and through averaging all symbols in small relatively uniform areas.

RECENT GEOPHYSICAL INVESTIGATIONS IN THE ATLANTIC OCEAN BASIN*

MAURICE EWING AND G. P. WOOLLARD

The onset of the war interrupted our scientific work and held up publication of results from the geophysical investigations in the ocean sponsored by the Penrose Bequest of the Society.

During the war period nearly all the established methods of submarine geology were found to have military application, and, as a result of the impetus given to such work by government research and development contracts, new techniques were developed. Thus the field work of the war period has both added considerably to the store of knowledge gained through established methods and has demonstrated the potential usefulness to submarine geology of entirely new instrumentation.

* This work represents one of the results of research carried out by the Woods Hole Oceanographic Institute under contract with the Office of Scientific Research and Development, Section 6.1, National Defense Research Committee and with the Bureau of Ships, Navy Department.

The co-operation of geophysicists, submarine geologists, and oceanographers with the Navy's research program has been particularly close and effective. It has led to improvements in the methods of both deep-sea and shallow-water seismic surveys, to advances in the techniques of underwater photography, and to the development of other rapid systems for collecting information about the sediments. Some examples of the results achieved by investigating workers at The Woods Hole Oceanographic Institution are presented.

As one example of an entirely new tool for the exploration of ocean basins a method of accoustically scanning the floor of the deep ocean is explained. This method is particularly promising for the location of active submarine volcanoes and isolated submerged sea mounts which cannot easily be found by conventional sounding techniques.

MAXIMUM ERROR IN SOME MINERALOGIC COMPUTATIONS

H. W. FAIRBAIRN AND C. W. SHEPPARD

The notable lack of quantitative information regarding errors in many mineralogic computations has prompted the writers to construct a series of diagrams from which such information can readily be obtained. These include various determinative methods for density, refractive index, birefringence, and optic angle. Assuming a skilled operator and good working material, maximum values of the error in single observations are assigned to each procedure, so that the diagrams depict "worst" values of error rather than "probable" error as determined by standard methods from a series of observations. Comparison of the various procedures is based on this maximum expected error.

LATE WISCONSIN VALLEYS OF THE LOWER MISSISSIPPI RIVER SYSTEM

HAROLD N. FISK

The position of buried stream valleys of the lower Mississippi system was established during geological investigation of the Mississippi Alluvial Valley conducted for the Mississippi River Commission. The valley system, reconstructed from a study of logs and samples from approximately 17,500 borings, was carved in the Gulf Coastal Plain sedimentary rocks when sea level was lowered by the withdrawal of oceanic waters necessary for the formation of the late Wisconsin ice caps. Melting of the glaciers raised sea level, and Recent alluvium buried the entrenched valleys. The valley bottom now lies 220 feet beneath the alluvial plain near Cairo, Ill., and 350 feet below the deltaic plain near Houma, La. Continuity of the principal trenches is well defined; the Missouri-Mississippi valley is west of Crowleys Ridge, and the Ohio trench is east of it. The two trenches meet near Rosedale, Miss., and are joined by the Arkansas west of Natchez, Miss., and by the Red near Melville, La. Alinement of the Mississippi trench beneath the deltaic plain of coastal Louisiana indicates that the Mississippi River entered the Gulf of Mexico west of its present mouth and near the head of the submarine canyon. After making corrections for regional subsidence, the slope of the valley floor projected seaward intersects the continental shelf between the 400- and 450-foot submarine contours. This figure provides a measure for the lowering of oceanic level during the late Wisconsin glacial stage.

PLEISTOCENE AGE OF THE "CITRONELLE"

HAROLD N. FISK

Fluviatile extensions of the four major coastwise terraces from Texas to Alabama have been traced in field studies to the head of the Mississippi Embayment. Each terrace is underlain by an alluvial sequence grading from basal gravel-bearing beds into overlying sands and silts. Each sequence reaches a maximum thickness of over 200 feet and exhibits the principal characteristics of the Recent alluvium of the Mississippi valley; it fills an older valley system cut far deeper than the channel of the present-day river. Each terrace sequence represents an oscillation in base level which is satisfactorily explained by the alternate withdrawal of water from the oceans to form the glacial ice masses and replenishment of oceanic waters through melting of ice. Continued epeirogenic uplift has separated the terraces and raised the highest one to over 600 feet above sea level at the embayment

head. The train of gravel-bearing sediments of the highest terrace extends coastward from the Ohio and upper Mississippi rivers, streams which were integrated and developed in early Quaternary time. Because the Citronelle formation at its type locality and in its mapped exposures in Mississippi and Louisiana falls within the terrain of the two highest terraces no support is given to its ascribed Pliocene age.

OCCURRENCE OF TUNGSTEN AND VANADIUM IN MANGANESE OXIDE ORES AND MINERALS*

MICHAEL FLEISCHER, S. K. NEUSCHEL, AND J. M. AXELROD

The occurrence of tungsten in manganese oxide ores was first noted by Penrose in 1890 and since has been discussed by several authors. Vanadium has been reported in four analyses of manganese oxides. New analyses in the Chemical Laboratory of the Federal Geological Survey have shown that these elements occur commonly in manganese oxide ores, especially in those from the southwestern United States. Over 50 new occurrences have been noted, and many more will doubtless be found by systematic chemical testing.

In some deposits, the tungsten and vanadium content of the ore varies directly with the manganese content, indicating that the tungsten and vanadium are in the manganese oxide mineral. This is not true of a few deposits, including that at Golconda, Nevada. X-ray study and chemical analysis show that tungsten and vanadium occur most frequently in manganese oxides that contain barium. Over three-fourths of the tungsten-bearing samples studied are the barium manganate psilomelane. Over two-thirds of the vanadium-bearing samples studied are either psilomelane or hollandite.

No generalizations can yet be made as to the origin of the tungsten-bearing and vanadium-bearing manganese oxide ores. Many are of hydrothermal origin, but some appear to be secondary.

AREAS GLACIATED DURING THE GLACIAL AGES

RICHARD FOSTER FLINT

Increasing knowledge of the limits of former glaciation on all continents has made possible more accurate recalculation of the areas formerly covered by glacier ice. Boundaries of the glaciated areas were plotted on an equal-area map, and the areas measured by planimeter. Some of the results differ notably from calculations based on earlier data.

Calculated areas (in square miles) of selected ice bodies at their maximum Pleistocene extent are: Laurentide Ice Sheet 5,071,000; Greenland Ice Sheet 935,000; confluent North American Cordilleran ice 957,000; Scandinavian Ice Sheet 2,145,000; Siberian Ice Sheet 1,628,000; Antarctic Ice Sheet 5,511,000; continuous ice in southern South America 297,000.

For the maximum of the latest glacial age, the calculations yield areas for the Laurentide Ice Sheet and the Scandinavian Ice Sheet equal to 4,840,000 and 1,650,000 square miles respectively.

Although an improvement on earlier data, these calculations are necessarily based in part on assumptions as to the extent of glacier ice over some land areas and especially over shallow areas now beneath the sea. This constitutes a source of error that may be large.

Data on the thicknesses of former ice sheets are less reliable than data on their areal extent. In consequence it is still not possible to make reliable calculations of the volumes of former large glaciers and hence to deduce the corresponding reduction of sea level.

Although probably the large glaciers were broadly contemporaneous in each glacial age, their maximum extents were not reached contemporaneously. This introduces further error into deduced changes of sea level.

MINERALOGY OF CONCRETIONS FROM PITTSBURGH COAL SEAM, MONONGALIA COUNTY, WEST VIRGINIA

WILDER D. FOSTER AND FLORENCE L. FEICHT

Four concretions were found in the Pittsburgh coal bed at Pursglove, Monongalia County, West Virginia, and were collected for study to get a better understanding of acid formation in the mine.

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Three of the concretions were mainly pyrite, and the fourth was mainly dolomite. Associated with one or more of these concretions were these minerals: analcite, brammallite, calcite, dolomite, kaolinite, melanterite, pyrite, and an unknown mineral. The Pittsburgh coal bed is of Pennsylvanian age and is the base of the Monongahela formation. Analcite has been found in sedimentary rocks, identified as a constituent of boiler scale, and synthesized under hydrothermal conditions. In all cases it has been formed under alkaline conditions; it is decomposed by acid. It is supposed that alkaline solutions containing sodium reacted with a clay to form the analcite. Acids in the coal bed could have been neutralized by ground water passing through a limestone bed a few feet above the coal.

Analcite was synthesized at atmospheric pressure and 90° C. by allowing NaOH solution to react on kaolinite for 29 days. Only a small amount was formed; most was unidentified material.

MORPHOLOGY AND HOMOLOGIES OF THE SIMPLE NUMMULITID FORAMINIFERAL TEST*

DON L. FRIZZELL

Three morphological elements comprising the operculine foraminiferal test (*Operculina* d'Orbigny, *Operculinella* Yabe) are considered fundamental for homologizing structures in the Nummulitidae: septal sheet, spiral laminae, and marginal cord (illustrated completely by Carpenter, 1862). The septal sheet is considered sparsely and coarsely perforate rather than, as Carpenter believed, very finely canalicular. ("Intraseptal canals" lie between adjacent septal faces.) The spiral laminae are perforate, composed of identical superimposed lamellae. The marginal cord is imperforate and canalicular. Secondary exogenous deposits thicken these structures without altering them.

Carpenter homologized the marginal cord with the "supplemental skeleton" of simpler perforate forms (as *Calcarina* d'Orbigny), and later workers have added the outer lamellae of the spiral laminae to the "supplemental skeleton." I homologized only the septal sheet as primary skeleton. "Supplemental" material overlying the septal sheet (marginal cord only) is imperforate and canalicular. Where it touches filose protoplasm (spiral laminae), it has a secondary perforate structure. The spiral laminae, except possibly in *Miscellanea* Pfender (Vaughan and Cole, 1942) constitute a homogeneous feature and must be treated as a unit structure. Homology of the "double wall" of *Miscellanea* demands only partial deterioration of the spiral laminae; the supposed "vertical canals" derive from normal tubules and are not homologous with the canal system of *Calcarina* or the camerinid marginal cord. This hypothesis argues considerably more specialization in the Camerinidae than previously postulated. Its virtue is in homologizing visible features of the test, rather than involving philosophical concepts of dual "primary" and "supplemental" origin of morphologically indivisible structures.

SECONDARY DAUPHINÉ TWINNING IN QUARTZ PRODUCED BY SAWING

CLIFFORD FRONDEL

Instances are described in which Dauphiné twinning has been formed artificially in quartz by sawing. The secondary twinning occurs as a very thin surface layer, usually on one side of the saw cut only, and seems to have been produced by frictional heat developed at the cutting edge of the saw blade. The twinning often is restricted to particular growth zones in the quartz. The tendency to twin is related to the tendency of the quartz to become smoky in color when irradiated with x-rays, easily twinned quartz being relatively little affected, and not to the original smoky color. The frequency-thickness constant, K, of easily twinned quartz is relatively low; and that of natural deep smoky quartz increases when the color is baked out. These observations and the apparently significant variations reported in the density, cell dimensions, rotatory power, and indices of refraction may stem from a defect structure in the substance.

The boundaries of some natural Dauphiné twins in quartz correspond with natural smoky color

* Presented by permission of the Director, Bureau of Economic Geology, Austin, Texas.

zones. In these specimens the original boundary of the twin is returned more or less exactly when the crystals are reinverted at 573° C., and a differential smoky coloration opposite to that existing initially is effected across the original twin boundary by radiation. Brazil and natural Dauphiné twins of colorless quartz sometimes also are differentially colored by radiation.

VALLEY EROSION SINCE PLIOCENE ALGAL LIMESTONE DEPOSITION IN CENTRAL KANSAS

JOHN C. FRYE

In central Kansas the Saline and Smoky Hill rivers flow eastward across Russell, Ellsworth, and Lincoln counties in broad, relatively deep valleys cut in limestone, shale, and sandstone of Cretaceous age. The abandoned partly filled Wilson Valley and contemporary Pleistocene terrace deposits and the recent discovery of remnants of the so-called Algal limestone—uppermost bed of the Pliocene Ogallala formation—on the upland surface between the two major valleys afford two known points in geologic time that can be used for measuring the quantity of valley erosion. After the deposition of the "Algal limestone" and prior to the placement of the Pleistocene fill in the abandoned Wilson Valley and on the major terrace level along Smoky Hill Valley, the major streams of the area cut through more than 150 feet of bedrock. After this period of erosion these valleys were partially filled with Pleistocene (Kansan?) stream deposits. Subsequently the Smoky Hill River has eroded its valley through 75 feet of bedrock plus a probable 60 feet of Pleistocene valley fill, and Saline River has cut its valley through more than 150 feet of bedrock plus a probable 60 feet of Pleistocene fill. The discrepancy in the amount of cutting of Saline and Smoky Hill valleys during the second period of erosion is accounted for by the Pleistocene drainage history of the region which has given the modern Saline River a shorter course than the Smoky Hill to their point of juncture.

GEOLOGY OF THE SOUTHERN END OF THE BLUE RIDGE IN GEORGIA

A. S. FURCRON AND KEFTON H. TEAGUE

The Blue Ridge province is terminated in Cherokee and Dawson counties, Georgia, by a northeast-trending shear zone which extends from Canton through Dawsonville to a point northeast of Dahlonega. Mount Oglethorpe, on the Dawson-Pickens county line, stands immediately northwest of this shear zone.

An extensive belt of sheared rocks extends along the west side of the Blue Ridge from its southern terminus east of Canton, Georgia, northeastward to the vicinity of Little Tennessee River, North Carolina. The rocks of this zone, probably mixed Lower Cambrian and pre-Cambrian, occur beneath (west of) a great Blue Ridge overthrust. They were divided into formations and classified as Lower Cambrian by previous workers. The writers question that interpretation because this shear zone contains sheared intrusions typical of the pre-Cambrian complex, and residual zones of unsheared, metasedimentary biotite gneisses. In this area four significant rock units are here recognized:

(1) Amicalola gneiss—the old pre-Cambrian complex here consisting of metasedimentary biotite gneiss with lenses of massive kyanite. This type of kyanite has been described previously only from India. The rocks are intruded by granites and hornblende gneisses.

(2) Murphy marble—coarsely crystalline, highly metamorphosed marble, which forms beds and lenses in Amicalola gneiss. It is intruded by hornblende gneiss and pegmatites. It is quarried, where unsheared, at Tate and Marble Hill, Georgia, and at Marble, North Carolina.

(3) Oglethorpe gneiss—a medium fine-grained biotite gneiss which overlies Amicalola gneiss, and which probably represents the later pre-Cambrian series of this region.

(4) Blue quartz-bearing conglomerate, sandstone, and dark slates. These rocks are generally slightly metamorphosed, are unconformable over the rocks described above, and probably represent basal Cambrian deposits.

FREQUENCY OF TWINNING IN QUARTZ CRYSTALS*

H. R. GAULT

More than 900 singly and doubly terminated quartz (low) crystals from five different geologic and geographic locations were etched with HF acid to show external twin boundaries. Most observations were made on the terminal faces.

In addition to untwinned crystals, twins of the Dauphiné, Brazil, combined Dauphiné-Brazil, and Liebisch types were observed.

The proportions of untwinned and twinned crystals and of twin types vary considerably from locality to locality. At each locality untwinned and Dauphiné crystals are about equally divided between right- and left-handed quartz. In Brazil, combined Dauphiné-Brazil, and Liebisch twins any one crystal is generally made up predominantly of either right or left quartz. They also occur in about equal proportions.

At least 100 crystals from a given locality should be examined to determine the frequency of twinning.

Further work is in progress to determine if in some cases twin boundaries are confined to the interior of a crystal.

ARMY-G.S.A. HELICOPTER EXPEDITION TO PARÍCUTIN VOLCANO

L. C. GRATON, E. T. NICHOLS AND W. F. FOSHAG

Report on the examination of Parícutin by helicopter, made possible by the Society's grant and the co-operation of the Air Service Technical Command of the Army, is best presented by means of the visual evidence secured by photography. This offering therefore consists of selected footages of Kodachrome cine film taken in part from the helicopter slowly moving above the rim and in part from positions on the rim itself. The configuration of the funnel as it changes with time, and various phases of eruptive activity (except those of greatest violence) emerging from the actual throat, are set against characteristic behaviors of the kind more commonly seen: bomb showers, lava flows, and spouting *volcancitos* or spatter cones. Running oral comment will attend the projection.

MICA-BEARING PEGMATITES IN THE SOUTHEASTERN STATES*

W. R. GRIFFITTS, E. WM. HEINRICH, R. H. JAHNS, J. C. OLSON, AND J. M. PARKER, III

Mica-bearing pegmatite has been mined extensively in the southeastern United States, particularly in 11 well-defined districts. The Spruce Pine and Franklin-Sylva districts in the Blue Ridge province of North Carolina, and the Alabama and eastern Virginia Piedmont areas are geologically representative of the entire group. Nearly all the deposits occur in mica and hornblende gneisses and schists and appear to be genetically related to near-by leucocratic intrusives that range from quartz monzonite to quartz diorite. About four-fifths of the pegmatites in the Alabama and Spruce Pine districts are sills or concordant tongues and lenses; most of the others in the Spruce Pine district are dikes in coarse-grained granodiorite and quartz diorite. In contrast, most of the Franklin-Sylva and Virginia pegmatites are steeply dipping dikes, discordant lenses, and more complex bodies.

Plagioclase, quartz, microcline, and muscovite are the dominant pegmatite constituents. Biotite, garnet, and apatite are common accessories; beryl, tourmaline, and sulfide minerals are sparse but widespread in some districts; and lithium, tantalum-columbium, tin, and uranium minerals are rare except in a few Virginia deposits. Nearly all the pegmatites appear to have formed from the walls inward, perhaps by crystallization from liquid. Definite evidence for or against their development by large-scale, complete or nearly complete replacement of pre-existing pegmatite is almost lacking. Although some of the minerals and mineral aggregates plainly were formed by replacement, only a small proportion of material can be assigned such an origin with assurance.

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HIGH-TEMPERATURE THERMAL EFFECTS OF CLAYS AND RELATED MATERIALS*

R. E. GRIM AND W. F. BRADLEY

A selected series of clay minerals and related silicates are examined by thermal, optical, and x-ray diffraction methods with a view toward establishing the significance of the various observed thermal effects. The heating range for the thermal curves is extended to 1300° C., and the study of specimens so fired is supplemented by the examination of the various materials after firing to several intermediate temperatures.

Detailed hypotheses are presented for the mechanisms of several of the structural changes observed as new phases are developed, and the influence of types of structures upon the nature and rapidity of such changes is discussed.

ISOSTRUCTURAL RELATIONSHIP OF $AlPO_4$ AND $SiSiO_4$

JOHN W. GRUNER

Huttenlocher (1935) has shown that the structure of AlP_4 and α quartz are very closely related. Their optical properties, densities, and hardnesses are also surprisingly similar. Their unit cells are almost identical in size except for a doubling of the c axis. Struntz has shown (1942) that berlinite found in Sweden and listed in mineralogy texts as $AlPO_4 \cdot H_2O$ is identical with $AlPO_4$ possessing the quartz structure. The author has confirmed the experiments of Huttenlocher and has been able to grow needles of $AlPO_4$ on sand grains of quartz in oriented patterns, also on some faces of quartz crystals.

In other experiments with $AlPO_4$ in bombs between temperatures of 150°–250° C. microscopic snowflake-like crystals of α tridymite structure were formed. These have indices close to 1.46. Their density is in the neighborhood of 2.30. Wavellite and variscite when heated in a crucible to low redness for a short time also assume the structure of tridymite. Under certain conditions in bomb experiments between 300° and 480° C. $AlPO_4$ forms cristobalite structures. The very small almost microscopic aggregates have indices of $1.465 \pm .002$ and a density of 2.28–2.29. The $AlPO_4$ α quartz structure (berlinite) will slowly invert to the cristobalite structure at 850° to 1000° C. Amorphous chemical precipitates of $AlPO_4$ when heated to 675° C. or above give the cristobalite X-ray pattern. The writer does not believe that a β tridymite structure of $AlPO_4$ exists.

CHROMITE DEPOSITS OF CAMAGUEY PROVINCE, CUBA†

PHILIP W. GUILD AND DELOS E. FLINT

The chromite-bearing ultramafic complex near Camaguey, Cuba, mapped as a part of the program of mineral investigations of the Federal Geological Survey, consists chiefly of serpentinized peridotite (harzburgite) and dunite, with minor amounts of the feldspathic rocks gabbro, troctolite, and anorthosite. This complex and the overlying Cretaceous tuffs and limestones were severely deformed in an orogeny which culminated in extensive thrust faulting, probably in late middle Eocene time. The sedimentary rocks now occur in two synclinal arcs extending across the district parallel to the trace of the thrust. The feldspathic rocks of the complex flank the tuffs along the limbs of the syncline, indicating that they were concentrated in the upper part of the complex.

The chromite occurs as tabular or lenticular bodies of massive, coarse-grained, or occasionally fine-grained disseminated ore. Virtually all the known deposits are near the base of the feldspathic zone, but with an irregular lateral distribution which distinguishes them from the layered chromitites of the Bushveld-Stillwater type. Two possible modes of origin are discussed: (1) segregation of the deposits near the feldspar-peridotite boundary after emplacement of the magma through some process of gravity separation and magmatic flow; (2) differentiation of chromite at great depth before intrusion and transportation of the ore bodies as solid masses to their present position. The grouping into clusters, as though near feeders, and the massive texture and sharp contacts of many of the deposits suggest that the latter hypothesis is more probable.

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ARTIFICIAL RECHARGE OF GLACIAL SAND AND GRAVEL WITH COLD FILTERED RIVER WATER AT LOUISVILLE, KY.*

W. F. GUYTON

Records obtained by the Geological Survey, United States Department of the Interior, and the Geological Division, Kentucky Department of Mines and Minerals, indicate that industries at Louisville pumped about 62 million gallons a day of water from wells in 1943. This was over 20 million gallons a day more than the natural recharge to the glacial outwash sand and gravel from which the wells draw the water. The ground water is especially in demand because of its uniform low temperature throughout the year. In order to stop the resulting serious decline of water levels and decrease in yields of wells, the pumpage is now gradually being reduced. Also, the recharge has been increased about 2 million gallons a day by introducing water into the aquifer through wells.

During the spring of 1944 the Seagram and National distilleries helped solve a local shortage of ground water by recharging the underground reservoir with 1.7 million gallons a day of cold water from the municipal river-water supply. While this water was being added to the aquifer through several supply wells the plants were operated with additional city water, and the rest of the supply wells were kept idle. In this way, the large cone of depression in the water table that had been created by heavy pumping from the wells was practically filled with cold water from a combination of natural and artificial recharge. As a result, during the summer when the city water became too warm to be used in the plants, an increased and ample supply of cold water was available from the wells. It has been suggested that other industries at Louisville might adopt similar procedures for insuring adequate supplies of cold water during the summers.

ANALYSIS OF SOME PHYLOGENETIC TERMS, WITH ATTEMPTS AT REDEFINITION

OTTO HAAS AND GEORGE GAYLORD SIMPSON

The terms analogy, homology, homogeny, homoplasy, divergence, parallelism, convergence, homeomorphy, mimicry, time signatures, recurrence, iteration, and others are traced back to their origins and critically analyzed. The following is concluded:

Owen's (special) homology should be restricted to similarities between parts, organs, or structures of different organisms attributable to common ancestry; homogeny (Lankester) then becomes a synonym of homology.

Homoplasy (Lankester) brings about similarity between organisms or their parts, organs or structures, due not to common ancestry but to independent acquisition of the similar characters. Analogous variations (Darwin), homomorphy (Palmén), isomorphism or isomorphy (Parker, Fuerbringer), homeogenesis (Eimer), morphological equivalents (Hyatt), and independent homologies (Hubbs) are considered synonyms of homoplasy. Homoplasy includes both convergence and parallelism, distinction between which should be based on whether or not similarity increases with evolution rather than on degree of relationship between the lines involved.

Convergence may lead to homeomorphy; this term ought to be restricted to similarities affecting the whole outer appearance of the homeomorphs and reaching such a degree that the one may be mistaken for the other unless certain internal or obscure characters are examined. Homeomorphy is not equivalent to, nor does it include, mimicry, but the concepts overlap.

Dacqué's terms *Zeitformenbildung* and *Zeitbaustile* are rejected; his *Zeitsignaturen* (time signatures) is admitted as a descriptive, not explanatory, term to designate isochronous cases of parallelism or convergence.

Recurrence of morphologic types may be merely homeomorphic recurrence or attributable to Koken's "iterative *Artenbildung*" (iterative formation of species = Beurlen's iteration).

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BERYLLIUM AND TANTALUM PEGMATITES OF COLORADO*

JOHN B. HANLEY

The beryllium and tantalum minerals of Colorado pegmatites are found together in the same structural units of the pegmatites, but in a variety of mineralogical associations. Beryllium-tantalum pegmatites are particularly abundant in Larimer, Fremont, and Gunnison counties, although a few occur in other parts of the State.

During detailed mapping in 1942–1944 by geologists of the U. S. Geological Survey, 51 individual pegmatites containing concentrations of beryl, chrysoberyl, columbite-tantalite, or microlite were studied. The largest concentrations of these minerals are in the intermediate zones of the pegmatites, although minor concentrations occur in all zones.

Beryl, the most common beryllium mineral, commonly is subhedral to euhedral and has a high beryllia content. It is associated chiefly with albite, muscovite, and quartz, as at the Devil's Hole, Mica Lode, and Hyatt Ranch pegmatites, or with lepidolite, cleavelandite, and quartz, as at the Brown Derby and the Meyers' mine pegmatites. Chrysoberyl appears to be most abundant at the Wisdom Ranch pegmatite but is not very abundant in any pegmatite.

Columbite-tantalite is the most widespread tantalum mineral. Commonly it is associated with beryl, albite, muscovite, and quartz and occurs particularly in the intermediate zone, for example at the Devil's Hole, Bigger, and Meyers' Ranch pegmatites. Microlite is common in the pegmatites of the Quartz Creek district, where it occurs with beryl, lepidolite, cleavelandite, topaz, and quartz. The Brown Derby and White Spar No. 1 pegmatites show examples of this association.

TIN AND TUNGSTEN DEPOSITS OF FRENCH MOROCCO

E. T. HECK

The only known deposits of tin and tungsten ores in French Morocco are located near Oulmes about 75 miles east of Casablanca.

The mineralized area at the El Karit tin deposit is confined to a zone of sedimentary rock along the northwest side of a granite boss. The tin occurs as cassiterite in and along quartz veins. The deposit has been worked to some extent, and the presence of ore has been demonstrated over an area 2.5 to 3 miles long and 800 to 1600 feet wide.

About 3 miles southwest of the El Karit deposit is another mineralized area known as the El Zguit tungsten deposit. The ore occurs as wolframite, ferberite, and scheelite, along the margins of a few large quartz veins. The only production from the deposit has been from exploratory trenching. Most of the work has been done on two veins, and mineralization has been found over a length of possibly 2 miles.

Both deposits are judged to be of commercial grade.

BISMUTH MINERALS IN COLORADO AND NEW MEXICO PEGMATITES*

E. WM. HEINRICH

Bismuth carbonates occur in pegmatites in Fremont, Park, and Gunnison counties, Colorado, and in the Petaca district, Rio Arriba County, New Mexico. In many deposits they appear to be alteration products of late-stage fracture-filling bismuth sulfides or sulfosalts. The most common species is bismutite (Bi_2CO_6), but beyerite, a carbonate of bismuth and calcium, was identified by x-ray powder methods from two localities.

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COMPOSITE PEGMATITES OF THE FRANKLIN-SYLVA MICA DISTRICT, NORTH CAROLINA*

E. WILLIAM HEINRICH

Granite occurs in 11 mica-bearing pegmatites in the Franklin-Sylva district, North Carolina. In some it is flanked by later pegmatite, but in others it appears to have been intruded along the central part of the pegmatite during the final stages of pegmatite consolidation. Granite also occurs as inclusions and as narrow dikes that cut across the mica deposits. Both rocks appear to be related in origin to the large masses of Whiteside granite that lie along the southeast side of the mica district.

PORTABLE DIFFERENTIAL THERMAL ANALYSIS UNIT FOR BAUXITE EXPLORATION†

STERLING B. HENDRICKS, SAMUEL S. GOLDICH, AND REUBEN A. NELSON

A small differential thermal analysis unit that embodies the fundamental features of larger laboratory models is designed for field exploration for bauxite and related materials. The apparatus, requiring only a source of electrical power, combines portability with ease of operation and rapid analysis. The portable unit is suitable for quantitative work and has been successfully applied in bauxite exploration on the island of Hispaniola.

STRUCTURAL RELATIONS OF THE UPPER MISSISSIPPI VALLEY ZINC-LEAD DISTRICT‡

ALLEN V. HEYL, JR., AND ALLEN F. AGNEW

The district includes southwestern Wisconsin and adjacent parts of Illinois and Iowa.

The immediate rock succession is middle Ordovician limestones and dolomites, with subordinate shales.

The probable mineral paragenesis is quartz, dolomite, pyrite, sphalerite, galena, marcasite, barite, chalcopyrite, and calcite.

The district is on the southwest limb of the Wisconsin arch, which gives a general southwest dip to the rocks. Superimposed upon this regional structure are broad, gently dipping eastward-striking folds and northwestward-trending basins. The eastward-striking folds are thought to have been formed by north-directed forces as the northern limbs dip more steeply than the southern ones. Minor folds, with an amplitude of 20 to 70 feet, that are subsidiary to the broad eastward-striking folds, form prominent local structures.

At least two types of faulting are recognized, reverse faults and vertical tear faults. Nearly flat bedding-plane faults in the basal incompetent Galena beds steepen upward in the competent beds to about 45°. They, in general, are confined to the limbs of the basins and tend to swing around the basins to form arcs or ellipses. The tear faults strike northwest or north and cut the fold structures.

The zinc-lead ore bodies border the subsidiary eastward-striking folds, and their localization is controlled by the reverse faults. The ore fills the faults and tends to spread in "flats" along the bedding planes in the footwall. Ore is also found along nearly vertical joints or minor reverse faults that parallel the axes of the northwestward-trending basins.

All structures are assigned either to north-directed or southwest-directed forces or a combination of both. They form a pattern consistent throughout the district; this, plus their magnitude, excludes the older explanation of collapse. Minor thinning of the beds by solution and replacement occurs.

LATE CENOZOIC FAUNULES IN SOUTHWESTERN KANSAS

CLAUDE W. HIBBARD

An aggregate of late Cenozoic deposits totaling a thickness of 551 feet occurs along the Cimarron River and its tributaries in southwestern Kansas and northwestern Oklahoma.

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The Rexroad formation contains two faunules, both of which are considered as having lived in a rather humid and mild temperate climate. The older faunule is the Saw Rock, which contains *Dipoides*. The younger fauna, the Rexroad, is Blancan in age.

The Meade formation which overlies the Rexroad contains three faunules. The oldest faunule, as yet unnamed, occurs at the base of the Meade and lived in that area during a glacial stage. The Cudahy fauna, also glacial in age, is found near the top of the formation just below the Pearlette ash. Above the Pearlette ash occurs the Borchers faunule which lived in that area during an interglacial stage.

The younger formations are the Odee, in part, and the lower and upper Kingsdown silt. Near the top of the upper Kingsdown silt is found the Jones faunule which is considered to have lived in that area during a glacial stage.

SCABLAND AND OKANOGAN LOBES OF THE CORDILLERAN GLACIATION, AND THEIR LAKE HISTORIES

WILLIAM HERBERT HOBBS

In the summer of 1943 evidence was found of a lobe of the Cordilleran glaciation which in late Wisconsin time occupied the "Scabland" region of Eastern Washington. Its area had been about 4000 square miles. Along its front was a peripheral zone of outwash gravels; this is surrounded by a much wider zone of silt (loess), today rich wheatlands.

The Scabland Lobe blocked the Upper Spokane Valley and impounded its great volume of glacier meltwater, then further augmented by the floods which poured in through the Clark Fork outlet of Glacial Lake Missoula in Montana. Lake Spokane had outlets into the Snake, first as border drainage to the lobe; but later into the Snake or the Columbia through successively unblocked channels which had been under the lobe.

When the Scabland Lobe had been liquidated and the glacier front stood north of the Spokane valley, Lake Spokane expanded far down the Columbia Canyon to where it was then blocked by the retiring Okanogan Lobe at Bridgeport above the "Big Bend." This ice dam produced Glacial Lake Leverett, which was more than 300 miles in length with outlets through the Grand and the Moses coulees.

With the retreat of the glacier front westward across the Okanogan valley Glacial Lake Okanogan, entirely within that valley, succeeded Lake Leverett. It was blocked, not by the glacier itself, but by the heavy moraines which cross the valley at Chelan.

SO-CALLED "IOWAN" GLACIATION: THE OUTWASH FROM THE DES MOINES LOBE OF THE LATE WISCONSIN GLACIATION

WILLIAM HERBERT HOBBS

That the so-called "Iowan" glacial deposits within Iowa were not deposited as the till of a glacier seems to be proven by the following considerations:

Negative: (1) The deposits do not have the outline of a glacial lobe; (2) their material is not till; (3) the surface of the deposits lacks the characteristic till features; (4) in place of a marginal moraine the beds thin outward.

Positive: (1) The "Iowan" deposits proceed from the eastern border of the Des Moines Lobe of the latest Wisconsin glaciation, where a rapid liquidation of that lobe occurred as shown by the exceptionally large recessional moraine interval; (2) the outline of the deposit is characteristic of heavy floods charged with much rock debris and moving on gentle slopes; (3) the underlying surface is a flat trough with low gradient southeastward; (4) the deposits are imperfectly bedded gravels with many included ventifacts, such as are common to outwash plains; (5) on all sides but the west they are surrounded by heavy loess deposits; (6) the giant boulders strewn over the central area of the "Iowan" duplicate those of the Des Moines Lobe and were probably transported in ice rafts propelled by the winds of the glacial anticyclone during the concluding stage of Des Moines Lobe liquidation within this neighborhood.

WHITE ARSENIDES OF NICKEL AND COBALT OCCURRING AT FRANKLIN, NEW JERSEY

RALPH J. HOLMES

Koenig, in 1889, described a white arsenide of nickel and cobalt from Franklin, noting that the material was "generally prismatic" but exhibited isometric crystal forms. He regarded both the massive prismatic material and the encrusting isometric crystals as a single homogeneous mineral, chloanthite.

Several specimens agreeing with Koenig's description were studied. X-ray diffraction and microscopic data show this material to be a complex mineral assemblage instead of the single isometric arsenide Koenig assumed it to be. An isometric arsenide, skutterudite, containing both cobalt and nickel, is present but is a minor constituent, encrusting nodular masses of rammelsbergite intergrown with pararammelsbergite (Koenig's "prismatic" material). The orthorhombic nickel arsenide nodules are in part rimmed by gersdorffite.

Data on the properties and relations of the several minerals are presented. Rammelsbergite and pararammelsbergite are shown to be the principal white arsenides of cobalt and nickel in the specimens observed. The presence of an isometric arsenide, skutterudite, is confirmed, but this is a minor component. Pararammelsbergite and gersdorffite, not previously reported, are added to the ever-growing list of species for this locality. The presence of rammelsbergite has already been pointed out by the writer, The recognition of skutterudite does not add to the total since it merely replaces Koenig's term chloanthite for the isometric arsenide.

PREGLACIAL PHYSIOGRAPHIC FEATURES IN ILLINOIS*

LELAND HORBERG

A bedrock-surface map compiled mainly from well records indicates that the bedrock topography of the State, now largely buried below glacial drift, may be divided into the following preglacial physiographic divisions: (1) a Niagaran cuesta in northeastern Illinois, (2) an upland on the Galena dolomite in north-central Illinois, (3) a Niagaran cuesta in northwestern Illinois, (4) an upland on the Pennsylvanian rocks of western Illinois, (5) an upland on Meramec-Osage limestones in western Illinois, (6) a lowland on the Pennsylvanian rocks of central Illinois, (7) Shawnee section, (8) Salem Plateau, and (9) Coastal Plain; the last three coincide with the present divisions of Fenneman for the driftless area of southern Illinois.

In the drift-covered section of the State possible remnants of three erosion surfaces are represented by: (1) bedrock upland surfaces 700 to 950 feet above sea level in northern and western Illinois, (2) bedrock upland surfaces 500 to 650 feet above sea level in central Illinois, and (3) broad bedrock lowlands 400 to 450 feet above sea level developed along major bedrock valleys. A final "deep valley" stage is represented by preglacial drainage systems with valley floors less than 300 feet above sea level.

STUDY OF *TRIGONOCARPUS* AND RELATED SEEDS OF THE PALEOZOIC

J. H. HOSKINS AND A. T. CROSS

Trigonocarpus was the generic name applied to the first fossil seeds to be described both as casts and as petrifactions. Seeds assigned to this genus have a widespread and abundant occurrence geologically and geographically, but their structure and identity have often been misinterpreted.

These seeds may be found in at least five distinct forms depending on the mode of preservation and stages of completeness. In several cases generic designations have been made for these more or less incomplete forms. Even more often specific rank has been given to some of these on the basis of apparent distinctions which are doubtlessly attributable to varying states and modes of

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preservation. Actual identification and determination of relationships are difficult by superficial characteristics and are unreliable unless some distinguishing histological details are preserved.

The study of some large, complete, well-preserved seeds found in some coal balls from a Des Moines series coal of Iowa has led us to conclude that the logical designations for three-ribbed, radiospermic seeds found as petrifactions, casts, and certain types of compressions *may* be *Pachytesta*, *Trigonocarpus*, and *Tripterospermum* respectively. An illustrated summary of the anatomical features characterizing the genus is given, and a brief comparison is made with some of the more closely related genera.

FAUNA OF CAMBRIAN METALINE FORMATION OF WASHINGTON

B. F. HOWELL

The Metaline formation of northeastern Washington has until now been correlated roughly with the Stephen formation of British Columbia. Further examination of its fauna indicates that it is of about the age of the fauna of the Lakeview formation of Idaho. It contains several species of the Lakeview fauna and some new species related to members of the faunas of the Damnation and Pagoda formations of northeastern Montana. The Metaline formation is therefore correlatable with the lower part only of the Stephen formation. Its fauna is older than the *Ogygopsis* fauna of Mount Stephen, British Columbia.

NORTH ATLANTIC MIDDLE CAMBRIAN SUBFAMILIES, NASSOVINAE AND ANOMOCARINAE, IN MONTANA

B. F. HOWELL

In 1937 Howell proposed the genus *Nassovia* and subfamily Nassovinae for certain trilobites from Vermont, New Brunswick, and Denmark. Poulsen's genus, *Elrathiella*, of Greenland and Montana, is also believed to belong in this subfamily. It is very similar to *Nassovia*, differing only in having a narrower rim and wider preglabellar area. *Nassovia* is found in the *Paradoxides hicksi* beds of southeastern Newfoundland and the somewhat younger *Paradoxides davidis* beds of Bornholm Island, Denmark. *Elrathiella* has been reported from the Pemmican River formation of northwestern Greenland and the Pentagon formation of Montana, both of which formations are believed to be a little older than the *Paradoxides hicksi* beds. *Glyphaspis dearbornensis* Deiss, a species of the subfamily Anomocarinae occurring in the Steamboat formation, which overlies the Pentagon formation in Montana and is probably of about the same age as the *Paradoxides davidis* beds of the North Atlantic region, is so similar to "*Anomocare*" *angelini* Grönwall, of the *Paradoxides davidis* beds of Bornholm Island, that the latter may prove, when its pygidium is discovered, to be a *Glyphaspis*. This tends to confirm the tentative correlations of some of the Middle Cambrian faunas of Montana with faunas in northwestern Europe that were made on the recently published correlation chart of the Cambrian formations of North America (1944).

GRADING AND ANALYSIS OF DIAMOND POWDERS

HERBERT INSLEY

The importance of grading of diamond powders and the elimination of outsize material from powders for commercial purposes is emphasized by illustration of the effects of improperly sized material.

Methods of grading powders and the standards of grade sizes for commercial use are described. The manner in which the establishment of methods of determining particle size and purity of diamond dust has already resulted in marked improvement in the quality of diamond powders is illustrated by photomicrographs of commercial powders before and after establishment of standards was undertaken.

COLOR CHARACTERISTICS OF SHEET MUSCOVITE IN THE SOUTHEASTERN STATES*

RICHARD H. JAHNS

Sheet muscovite in the Southeastern States ranges from buff, drab, and pale reddish brown (so-called ruby micas) through shades of brown (rum micas) and green to pale yellowish green. The deepest shades are olive and greenish browns, the lightest yellowish green, buff, and drab. Field and laboratory studies of more than 3500 samples reveal systematic color variations within individual books, within some mica shoots, within single pegmatite bodies, and within large groups of pegmatite bodies. Several generalizations, based in part upon field observations of W. R. Griffitts, E. Wm. Heinrich, J. C. Olson, and J. M. Parker, III, are:

(1) Many books are color-zoned, with gridiron or chessboard patterns, concentric color bands parallel to crystal outlines, stripes parallel to pressure figures, or faint, irregular mottling. These features commonly are confined to certain sectors of a book.

(2) Nearly all books contain pale rims that tend to be more greenish than the interior. These appear to be secondary and are analogous to bleached areas along cracks and around pinholes and inclusions.

(3) "A" structure is more common in green than in brown books.

(4) Biotite ordinarily occurs near or intergrown with reddish-brown muscovite, rarely with green.

(5) Mineral stain occurs predominantly in green muscovite and rarely with biotite.

(6) Garnet is a characteristic associate of green muscovite, apatite of reddish-brown muscovite.

(7) Color variations in individual books and within single mica shoots are most pronounced where the muscovite is light to olive green.

(8) Green books generally are younger than brown within a single deposit, and nearly all very late-stage books are pale to yellowish green, small, and yield little sheet material.

(9) Color variations within most pegmatite districts are systematic, generally with respect to large granitic masses.

PENNSYLVANIAN RUGOSE CORALS FROM THE MIDCONTINENT REGION

RUSSELL M. JEFFORDS

Marine Pennsylvanian deposits of the Midcontinent contain a varied assemblage of fossil corals. Detailed studies of the internal structures of a large collection of corals indicate the occurrence of many species that may be grouped into distinct genera. The small solitary column-bearing types are especially numerous throughout the Pennsylvanian, and a large number of short-ranging species are assigned to *Lophophyllidium*. Caninoid corals (=*Campophyllum* of authors) occur commonly also, and preliminary investigations indicate the presence of several restricted species. *Dibunophyllum*, *Lophamplexus*, and corals of the zaphrenthoid type are less widely distributed, but they are represented by several species that are abundant locally.

The short range of many of these species and their abundance suggest possible wide stratigraphic usefulness of the coral faunas. Certain types of rugose corals are restricted to particular environments so that superficial similarity may exist between forms from widely separated horizons.

LIME-SECRETING ALGAE FROM THE PENNSYLVANIAN AND LOWER PERMIAN OF KANSAS

J. HARLAN JOHNSON

Twenhofel (1919) described algal material from the Pennsylvanian and Lower Permian beds of Kansas, and later writers have repeatedly mentioned their occurrence. Moore and Elias (1937) pointed out that they occur quite consistently at certain positions in the depositional cyclothem.

Algae were collected from beds which range in age from the top of the Lower Pennsylvanian almost to the top of the Lower Permian. They came from 74 formations or named members.

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The algae described belong mainly among the green and blue-green algae (Chlorophyta and Cyanophyta) and include members of the families Dasycladaceae, Codiaceae, Porostroma, and Spongiostroma. The Dasycladaceae are represented by six new species of the genus *Epimastopora*, the Codiaceae by a new genus *Anchicodium* represented by six species. Four species of *Girvanella* are present.

The genera *Ottonosia* and *Osagia* named by Twenhofel are discussed, and details of their microstructure are given. The *Osagia* colonies are shown to consist of an intimate intergrowth of several different algae often associated with Foraminifera belonging to the *Nubicularia*.

Among the Spongiostroma described are the *Somphospongia* and several species of cryptozoans.

Locally the algae are very important rock builders. The relation of the algal deposits to the cyclothems is noted and discussed. (Geological Society project.)

NUBICULARIA FROM THE PENNSYLVANIAN AND PERMIAN OF KANSAS

J. HARLAN JOHNSON

The foraminiferal genus *Nubicularia* was named by Defrance in 1825. Modern representatives are known from warm shallow waters. Practically all are encrusting types. The genus has a long fossil record, being reported from both the Mesozoic and the Cenozoic of Europe. Recently the author, while studying fossil algae from the Pennsylvanian and lower Permian limestones of Kansas, encountered numerous occurrences of the genus. They range from the Altamont limestone of lower Mid-Pennsylvanian age up to the Fort Riley limestone which is near the top of the lower Permian.

Frequently these Foraminifera are associated with algae, and locally numerous small pelletlike fossils occur which are composed of an intimate intergrowth of Nubicularia with algae of several types.

The paper is illustrated by a plate of eight photographs.

QUARTZ CRYSTAL IN BRAZIL

W. D. JOHNSTON, JR. AND ROBERT D. BUTLER

The peak pr[illegible]uction of Brazilian quartz crystal was reached in 1943 when 2411 metric tons were exported. Mi[illegible] Gerais, Goiaz, and Bahia are the principal producing states. Minor quantities are obtained fr[illegible] Espirito Santo and Northeastern Brazil.

Primary vei[illegible]nd pegmatites yield secondary deposits of eluvial, colluvial, and alluvial origin. The veins range [illegible]form from tabular or lenticular bodies, pipes, and pockets to composite lodes and bedded masses. [illegible]he mineralogy is simple; accessory minerals are few and rare. A small proportion of clear cry[illegible]ls, occurring in vugs within the vein masses of milky quartz, furnishes the commercial product[illegible] Filling, rather than replacement, is believed to be the dominant emplacement process.

Pegmatites y[illegible]l a little commercial quartz. Both residual (eluvial) and water-laid (alluvial) quartz deposits [illegible] economically important.

Crystals range[illegible]) to 40 metric tons in weight; those of 1 to 5 tons occur in many deposits. Quartz from every local[illegible] studied is twinned on both the Brazil and Dauphiné laws. Phantoms are abundant.

Field studies re[illegible]al little difference between the final quartz from some pegmatites and that from veins. It is inferred that the veins may grade into pegmatites at depth and that both are products of the same mineralogenic epoch. Present evidence does not justify a closer dating for the formation of the veins and pegmatites than the early Paleozoic.

HIGHGATE SPRINGS SEQUENCE, NORTHWESTERN VERMONT AND SOUTHEASTERN QUEBEC

MARSHALL KAY

The Highgate Springs sequence of Middle Ordovician rocks lies structurally below and west of thrusts bounding the Rosenberg, Philipsburg, and Granby slices for 100 miles from Chittendon

County, Vermont, to Bagot County, Quebec. Three formations are Chazyan. The oldest exposed is the Beldens, white, dense limestone and buff-weathering dolomite, at least 500 feet thick. The Carman (type, 135 feet, Shipyard Bay, Highgate Springs) is fine-sand quartzite and argillaceous fine sandstone having some limestones toward the top, varying from 60 feet at St. Albans to 125 near St. Dominique. The Youngman (type, 300 feet, Mississquoi Park, Highgate Springs) is typically argillaceous *Christiania*-bearing limestone grading up into dark slate having limestone interbeds; northward near Bedford calcarenite interbeds are abundant; at St. Dominique is nearly 300 feet of argillaceous and quartz-silty limestone; southward near Fonda is dominantly dark, dense limestone; most of the Middlebury slaty limestone of west-central Vermont is equivalent. Disconformably overlying the Chazyan at Highgate Springs is 80 feet of Isle la Motte dark, dense, heavy-ledged limestone having lower Trenton fossils above basal calcareous quartz sandstone. The succeeding Glens Falls argillaceous limestone, 120 feet at Highgate Springs, has *Cryptolithus* and *Reuschella*, characteristic of Shoreham, 35 feet from the base. Canajoharie dark shale overlies.

The rocks, severely folded and faulted adjacent to major thrusts, are commonly overturned, younger beds locally forming anticlinal cores. The western limit is believed to be a major thrust, the sequence to the west differing particularly in the Chazyan.

NORTH AMERICAN GEOSYNCLINES—THEIR CLASSIFICATION

MARSHALL KAY

Geosynclines result from "long-continued subsidence" and "consequent accumulation of sediments" (Dana); the term is stratigraphic, contrasting with the structural "synclinoria." Classification of American geosynclines is based on their form and position, and the source of their rocks; they have limits of area and time. Examples are cited:

I. Linear geosynclines peripheral to the shield or craton—orthogeosynclines: (a) having volcanic rocks, cherts, and slates—eugeosynclines; coarser detritus from adjoining linear islands (Middle Ordovician, central New England to central Newfoundland); (b) lacking appreciable volcanics, clastics from craton (Cambrian of northern Rocky Mountains and Great Basin) or from uplifts in peripheral belts—miogeosynclines.

II. Geosynclines within the craton—parageosynclines of Stille: (a) marginal geosynclines gaining principal detritus from uplifts in orthogeosynclinal belts—deltageosynclines (Upper Ordovician and Lower Silurian, central Appalachians); (b) isolated within the craton, without adjoining uplifts—autogeosynclines (later Paleozoic, Michigan Basin); (c) similar but having complementing uplifts within the craton—zeugogeosynclines* (late Pennsylvanian, northwestern Colorado).

III. Geosynclines of later cycles: (a) Narrow, deep, peripheral geosynclines adjoining linear uplifts, lacking abundant volcanics—epieugeosynclines* (Pennsylvanian, Nova Scotia); (b) fault-bounded geosynclines in tilt blocks and grabens—taphrogeosynclines (Late Triassic, Connecticut); (c) deposits in synclinorial consequent basins (Eocene, southwestern Wyoming); (d) geosynclines passing marginally into present coastal plains—paraliageosynclines*, possibly parageosynclines of Schuchert—(Tertiary of Gulf Coast).

Geosynclines tend to have plural influences; the terms may be applied to types of deposits. Dana's original examples were of deltageosynclinal, taphrogeosynclinal, and eugeosynclinal deposits. American eugeosynclines resemble East Indian Tertiary idiogeosynclines; the development of the latter suggests the nature of the early Paleozoic marginal volcanic troughs.

* New.

TERTIARY IRON ORE IN TRIASSIC COLLAPSE BRECCIA*

VINCENT C. KELLEY

The deposit is 6 miles north of Capitan, New Mexico, in nearly flat-lying limestone of the San Andres formation (Permian) and near the west end of the large early Tertiary aplite intrusive of the Capitan Mountains. The ore, which is largely magnetite, forms nearly a ring about 1300 feet in

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diameter; the average width of outcrop is 100 feet. Although only two very small sills of aplite crop out near the deposit, an unusually large quantity of silicates has formed in the limestone, especially inside the ring of ore. The principal silicate minerals are epidote, phlogopite, and tremolite which are arranged in concentric zones outward in the order given. Magnetite forms the fourth or outer zone. All the minerals are present in the inner zone, but the characterizing mineral of a zone is not present in an outer zone. The deposits, which are genetically related to the intrusive, are located in a secondary breccia in the limestone. Solution by ground water, probably in early Triassic time, created a spongelike cavernous condition in the limestone which crushed gradually to form what is termed a collapse breccia.

CIRQUES IN NORTHWESTERN MICHIGAN

W. A. KELLY

Attention is called to the occurrence of small-scale cirques in the Porcupine Mountain area of northwestern Michigan. These forms were noted during the course of the preparation of a map of the area from aerial photographs. The Porcupine Mountains form part of a dissected plateau rising to a maximum elevation of nearly 1900 feet, the "Underwood" hill. The base of the plateau is sharply outlined in many places by the transition from steep border escarpment to the gently sloping Duluth glacial lake plain at an elevation of about 1150 feet.

Small cirques occur at an elevation of about 1500 feet. The flats of the cirque floors have areas ranging from 90 to 500 thousand square feet. The dimensions of a typical cirque are 500 feet from headwall to trough headwall and width of about 450. The escarpment at the head of the cirque is about 75 feet, the sides about 50 feet, and at the foot of the cirque the trough wall drops 100 feet abruptly. A small coniferous marsh occupies the upland basin.

BAUXITE "EGGS"

PAUL F. KERR

More or less spheroidal aggregates of bauxite are found at Poços de Caldas, Brazil, and in Surinam. These egglike shapes are believed produced by gel-shrinkage at a final stage in lateritization. The forms are at times hollow or may be filled with white gibbsite powder and exceed by several inches the usual diameters of pisolites. At Poços de Caldas joint blocks in phonolite are considered to have altered *in situ*, first to laterite, subsequently to bauxite "eggs." In Surinam relict outlines of earlier rock are retained in the spheroids. The interpretation of the significance of the forms is based upon field observations at Poços de Caldas and laboratory study of both sets of materials. Microscopic, x-ray, and chemical methods of investigation have been employed.

TERRAIN DIAGRAMS: THEIR GEOLOGICAL AND MILITARY APPLICATIONS*

PHILIP B. KING

Terrain diagrams, or physiographic diagrams, were extensively used during the war by the Military Geology Unit of the Geological Survey. By this means terrain features were represented in more graphic form than these features would appear on ordinary maps, and were thus more readily comprehended by users not accustomed to map interpretation. Various types of diagrams were prepared, some on map base, some in isometric projection, and some in true perspective, in part with the aid of various new mechanical devices. The methods of graphic presentation that were developed are also useful in illustrating geologic features and will be worth applying in the preparation of geologic reports.

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PLANT MICROFOSSILS FROM ILLINOIS COALS*

R. M. KOSANKE

Plant microfossils isolated from coal by the maceration process have been under investigation for the past 2½ years. Nearly 500 macerations have been run on the coals from the Pennsylvanian of Illinois. The present investigation deals entirely with the microspores, isospores, and prepollen. Megaspores have been isolated, and residue reserves saved.

The best general results in isolating plant microfossils from coal have been obtained with Schulze's solution followed by potassium hydroxide. The spores are stained in a concentrated solution of safranin in water and destained in alcohol in preparation for diaphane mounting.

The vertical and lateral distributions of the various genera and species have been determined. Numerous new species and a few new genera have been found. It seems possible to correlate most of the commercially important coal beds. Correlations have not been based on any one species but rather on the characteristic assemblage and zonation of spores found in the various coal beds. In addition to being a valuable aid in correlation, the study has revealed, so far as affinities of isolated spores are known, the vegetation that existed during the various coal formation periods.

Correlation of Illinois coal beds and the determination of the general type of vegetation within the coals are possible in well-organized studies of this nature.

THIRD SYMPOSIUM ON DIAMONDS

E. H. KRAUS, *Chairman*

The exigencies of World War II have greatly increased the demands for many minerals. Important new uses for some of them have been developed. This is true of the diamond, especially of its use for industrial purposes. This expanded use of the diamond is of necessity based upon a fundamental knowledge of its crystallographic and structural properties. In this respect the diamond differs markedly from many other raw materials.

At the Boston meeting of the Society, in December 1941, the first Symposium on Diamonds was held. Eight persons participated in the program. The symposium was very well attended, and the discussion of the various papers was very gratifying, for much new information was given to those present. It was agreed that a second symposium should be arranged for the next annual meeting of the Society in 1942. Although no annual meetings have been held since 1941, papers for a second symposium were prepared. The papers of both symposia were published in the March, 1942 and 1943, issues of the American Mineralogist. The demand for reprints in this country and from abroad has been unusually heavy. Since no symposium has been held since 1943, it is highly desirable that papers discussing the present status and trends, as well as the new developments, some of which are truly remarkable, in the use of the diamond should be presented. Accordingly, the following program has been arranged.

1—Introductory Statement	Edward H. Kraus, *Chairman*
2—Diamond Production	Sydney H. Ball
5—Gem Diamonds	Lazare and Leo Kaplan
6—Diamond-grinding Wheels	A. A. Klein and C. R. Van Riper
5—Observations on Orientation and Hardness Variation	Horace Winchell
6—Preparation and Standardization of Diamond Powder	Herbert Insley
7—Controlled Low Voltage Drilling and Reaming of Diamonds	Walter B. Emerson
8—Application of the High Voltage Arc to the Cutting, Sawing, and Spotting of Diamonds	Chauncy G. Peters
9—Development and Trends in the Use of Industrial Diamonds	Chester B. Slawson

Note: It is possible that additions may be made to the above program.

* Presented with the consent of M. M. Leighton, Chief, Illinois Geological Survey.

PHYSICAL AND CHEMICAL PROCESSES IN GEOLOGY

PAUL D. KRYNINE

The interpretation of geological processes requires an understanding of:

(A) Basic principles involved (different for each process)!

(B) Actual physico-chemical procedure (also different)!

(C) General over-all operative mechanism or framework which surrounds any locus of geological activity and involves the following common elements for all processes:

(1) Time (duration) of operation of the process:
   a. Total time involved.
   b. Portion of the time during which process operates effectively ("effective time").

(2) Intensity of the process
   a. Absolute or theoretical effectiveness (from very small to potentially very great).
   b. Effective intensity at any given point of the operational cycle, which means (1) overcoming threshold conditions, and (2) handling such increments or decrements of resistance as may develop as the process modifies the material; thus producing possible gradual self acceleration or self braking of the process and resulting in changing effectiveness for different parts of the operational cycle. The time interval during which maximum efficiency is maintained is far more important than any other period.

(3) Provenance control or influence of material involved in a process upon the effectiveness of this process.

(4) Over-all geological background. There are no closed systems in nature, and no process operates in a geological vacuum. Outside factors (either pre-existing or vicinal) may boost, reduce, or even reverse the net effectiveness of a process.

The concept is illustrated by discussing the formation of the same sedimentary body under variable conditions of diastrophism, relief, and available detritus.

MISSISSIPPIAN FORMATIONS OF SOUTHWESTERN NEW MEXICO

LOWELL R. LAUDON and ARTHUR L. BOWSHER

Detailed sections of Mississippian rocks have been measured, faunas collected, and correlations made in the Sacramento, Hueco, Franklin, San Andres, Cooks, Lemitar, Ladrone, and Mimbres ranges and in the Magdalena and Silver City areas.

The Caballero formation of Kinderhook age lies at the base of the section. The Osage series is represented by the Lake Valley formation at the base overlain unconformably by the Kelly formation. The Lake Valley formation is divided into six members. The Meramec series is represented by two formations originally classed as part of the Helms formation. The two formations carry the *Leiorhynchus carboniferum* fauna and are correlated with the Moorfield formation of Arkansas. The Chester series is represented by the restricted Helms formation.

FOUNDATION EXPLORATION AND GEOLOGIC STUDIES AT CHEROKEE AND DOUGLAS DAMS, TENNESSEE

ROBERT A. LAURENCE

Cherokee and Douglas dams were built by the Tennessee Valley Authority, under a war-emergency schedule permitting only 20 and 13 months construction periods, respectively. Both rest on foundations consisting largely of calcareous rocks. Therefore, interpretation of geologic features as related to foundation conditions was of prime importance to the construction staff.

At both sites, foundation defects were directly controlled by minor features of stratigraphy and geologic structure. At Cherokee these were (1) a network of solution channels along joints in two limestone beds in a shale formation, especially at and near minor folds and cross faults, (2) local deep weathering of calcareous shale beds, especially near the same minor structures, and (3) cavernous dolomite beds on a divide forming the reservoir rim.

Principal defects encountered at the Douglas site were (1) extensive solution openings under the river channel, especially along strike joints, (2) bedding-plane caves developed above thin cherty or shaly beds in the abutments, and (3) deep weathering in and near a deposit of volcanic ash and dolomite filling a pre-Chazyan sink hole.

Exploration, largely by diamond drills and large-diameter calyx drills, was carried on for six months before construction, as well as during much of the construction period, and invaluable geologic data were obtained from grout holes and daily observations in the excavated areas. Final limits of excavation, and methods and extent of foundation and rim treatment were adapted to the geological conditions to provide safe and water-tight structures.

OCCURRENCE AND DISTRIBUTION OF IRON MINERALS IN PENNSYLVANIA FIRE CLAYS

EARL LEATHAM

Millions of tons of flint fire clay occurring in Clearfield and adjoining counties of Pennsylvania are of no industrial value because of the high content of iron minerals. The amount of iron minerals expressed as Fe_2O_3 usually varies between 8 and 15 per cent. A study of the occurrence and distribution of the iron minerals was made to evaluate the possibility of removing the iron by beneficiation.

The contact-print method, as described by Gregorie Gutzeit (1942), was used because it was simple and rapid. Gelatin-coated white paper treated with the proper reagents was pressed against a polished surface of clay. A colored iron compound was formed opposite each iron mineral.

It was found that most of the iron occurred as siderite with minor amounts of pyrite or marcasite. There was marked variation in the size of the siderite crystals from different parts of the area. In one relatively small area, the siderite crystals averaged 0.5 mm. in diameter. Probably this clay could be beneficiated. Throughout most of the area, the diameter of the siderite crystals averaged less than 0.02 mm. It is doubtful if such clay could be beneficiated commercially.

ILLINOIS GEOLOGICAL SURVEY'S ACTIVITIES IN WAR AND PEACE

MORRIS M. LEIGHTON

This paper describes the unusual research program of the Illinois Geological Survey during the war and now, with the resumption of peace, its modification to serve a highly industrialized State with extensive mineral resources.

Thirty projects carried on by the government and by industry had direct bearing on the prosecution of the war. Nineteen of these concerned geology primarily, eight variously involved the combined fields of geology, geophysics, chemistry, chemical engineering, and petroleum engineering, four were primarily chemistry, and one was topographic mapping.

The peace-time program of the Survey will differ from the war-time program only in certain special respects. Fundamental work will now receive greater emphasis in stratigraphy, paleontology, paleobotany, clay mineralogy, coal petrography, X-ray, and spectrography, although not all of this work was suspended during the war, and chemical studies of the nature of coal, and certain chemical and physical technologic studies will be resumed. Mineral economics has been re-emphasized during the war period, and this will continue. Educational extension work among teachers of high school science and the citizenry will also be resumed.

This unusual program among State surveys was made possible by a period of 10 years of expansion and development before 1942, during which the geological resources section of the Survey was broadened, geochemistry, geophysics, and mineral economics were added, larger provision was made for dissemination of information, and two new buildings—a Natural Resources Building and an Applied Research Laboratory—were completed, equipped, and occupied within the year before Pearl Harbor.

NEW WASHITA FORAMINIFERA

ALFRED R. LOEBLICH, JR., AND HELEN TAPPAN

Thirty-one species of Foraminifera are described from the Washita group (Lower Cretaceous) of southern Oklahoma and northern Texas; 30 species are new, and the other is redescribed in the light

of more complete specimens. Four new genera, belonging to the Reophacidae, the Ophthalmidiidae, the Placopsilinidae, and the Anomalinidae are described. The geologic ranges of three genera, *Nodophthalmidium*, *Ophthalmina* and *Eouvigerina*, are extended downward to include the Lower Cretaceous.

HOW OLD IS THE COLORADO RIVER?

CHESTER R. LONGWELL

Published views that the present through-flowing course of the Colorado River does not antedate early Pleistocene time have been seriously questioned, and a critical appraisal of the known evidence is in order. Stratigraphic evidence west of the Colorado Plateau is as follows:

(1) The Muddy Creek formation, which is the youngest known interior-basin deposit through which the Colorado River has cut, may be as old as Miocene; Stock has suggested that the few unsatisfactory fossils thus far reported from this formation may indicate Miocene age.

(2) The oldest deposits of gravel and silt that can be ascribed to the Colorado River have yielded bones of *Camelops* sp., which the present writer once accepted as evidence of Pleistocene age; he is now informed that a date as early as Pliocene is not precluded.

At present, therefore, it can be said only that the course of the Colorado west of the Grand Canyon probably was established after some date in the Miocene epoch. A more exact statement must await more precise age determination of the critical deposits.

WAVE MODIFICATION OF ESKERS IN MAINE

RICHARD J. LOUGEE

Eskers in eastern and southern Maine commonly show in cross section a structure consisting of a ridgelike core of gravel overlain on the top and sides by several feet of marine clay, and this in turn overlain by a capping of gravel. The clay and upper gravel may contain plentiful marine fossils, but the underlying core of esker gravel lacks fossils. Similar structure in Sweden is interpreted by DeGeer to indicate that the clay settled on the esker ridge while it was beneath the sea, and later, as the sea floor emerged, wave action washed away the protruding knobs of the esker to form an apron of wave gravel on the clay-covered sides and lower parts of the crown of the esker.

Many eskers in Maine are so deeply buried in the surrounding marine clay beds that the fossiliferous capping of wave gravel and the underlying clay are almost the only exposed parts of the ridge, and little or none of the underlying esker is visible. Failure to distinguish between the reworked gravels and the esker proper has given rise to descriptions of eskers containing fossils deposited as the esker was formed. This in turn has led to a belief that the last ice sheet was so thin that it overrode, without disturbing the marine clay, and established a second generation of eskers upon the sea floor. DeGeer's simple explanation sufficiently accounts for all the evidence and avoids the confusion of some American writers on the subject.

THERMAL GRADIENTS AS A RECORD OF RATE OF OXIDATION AND OF RECENT CLIMATIC CHANGES IN ARIZONA*

T. S. LOVERING

Thermal gradients measured in 11 churn drill holes in the San Manuel district, near Tucson, Arizona, all have two inflection points, and some have three. Changes in slope may be caused by: (1) differences in conductivity, (2) changes in surface temperature, (3) subsurface heat sources or sinks.

(1) The slight differences in conductivity did not appreciably affect the San Manuel gradients.

(2) Gradients calculated on climatic changes, suggested by historical records and by tree-ring studies, from warm to cool in 1600 A. D. and cool to warm about 1880 give perfect fits for the three gradients where the sulfide zone is 200 feet or more below water level.

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(3) The most marked departure from the calculated curves is in gradients where sulfides are above or at water level. The difference in slope between observed and calculated gradient at the top of the sulfide zone indicates a gradient of about 0.6°F. per 100 feet due to oxidation of pyrite. This is equivalent to a heat source of about 0.15 cal per cc of pyrite per year. At this rate it would require about 90,000 years for the complete oxidation of this pyrite. The rock is relatively tight and contains less than 5 per cent pyrite; a larger proportion of pyrite fuel or more open ground favoring faster oxidation could increase the oxidation gradient many times.

ALTERATION AND STRUCTURE IN THE EAST TINTIC DISTRICT, UTAH*

T. S. LOVERING, W. M. STOLL, A. H. WADSWORTH, H. C. WAGNER, B. F. STRINGHAM, L. S. HILPERT, J. F. SMITH, ALBERTO TERRONES

In the East Tintic district, east of Eureka, Utah, large blind limestone replacement ore bodies lie below strongly altered quartz latite flows. Cambrian quartzite, shale, and limestone cut alternately by steep-angle and low-angle faults of at least three tectonic episodes separated by intervals of folding were deeply eroded before the lava was extruded. Minor movement along the earlier fractures subsequently accompanied intrusion of quartz monzonite porphyry and preceded the deposition of ore. The basement rock and the many tectonic events make the area ideal for studying the processes and duration of alteration. Five stages are recognized: (1) Early barren stage, characterized by extensive hydrothermal dolomite and minor chloritic alteration, and contemporaneous with earliest volcanism; (2) Mid-barren stage, dominantly argillic alteration preceding and accompanying first intrusions of quartz monzonite porphyry and characterized by widespread dickite, kaolinite, halloysite, beidellite and rutile, with quartz and alunite locally abundant; (3) Late barren stage, an allophane-quartz-barite alteration that immediately preceded ore and was almost restricted to the channels of mineralization deposition open during the ore stage; (4) Productive stage, marked by ore deposition, sericite, and hydromica; (5) Weathering stage, with montmorillonite as the characteristic mineral.

Leaching, transfer, and redeposition in different form can be traced in several phases of the alteration, but no source is evident for some of the material added in certain types of alteration. The magnesium for hydrothermal dolomite is probably magmatic; the acid radicles in the solutions that effected the argillic alteration may be the only magmatic contribution during the mid-barren stage; barium, sulphur dioxide, and carbon dioxide are the chief constituents ascribable to the magma during the late barren stage, but nearly all the material added during the productive stage is probably magmatic.

The acid leaching of, and transfer of potash and silica from warm quartz monzonite bodies during the mid-barren stage is reflected in silicic and potassic halos around the partly argillized intrusives. Replacement of dolomite and limestone by jasperoid and ore is reflected by a calcitic replacement of the lavas above. Nearly neutral ore solutions are suggested by the lack of other alteration during the formation of disseminated pyrite in the lavas above.

The altering solutions and the sequence of alterations—(1) magnesium, (2) argillic or acid, (3) silicic and carbonic acid, (4) potassic and sulfidic—are believed to be of general occurrence in western mining districts, though the mineralogy may vary with the character of the rocks and the physical conditions that obtained during the alteration.

CONSTRUCTION AND STUDY OF FLOW-STRUCTURE MODELS FROM FIELD DATA

KURT E. LOWE

Investigators of intrusive rocks on a regional or reconnaissance scale frequently lack both time and facilities for petrofabric study with the universal stage. Limited or inadequate exposures may add to the difficulty of ascertaining flow structures in the field. The construction of transparent models based on field measurements has proven helpful in the study of the Storm King granite of the Hudson Highlands and is suggested as a useful laboratory and training device.

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Field measurements are made on 8 to 10 exposure surfaces of varying orientation including strike and dip of surface, pitch of lineation, mineral pattern (field sketches), fracture systems. A plan of the model is laid out on graph paper, starting with a top horizontal plane bounded by lines of intersection (strike lines) with the measured inclined surfaces suitably grouped by parallel translation. For a given model height, auxiliary scales are prepared for the vertical projection (A) and true length (B) of planes dipping 0° to 90°. The ground plan is drawn (using A) and the cut-out pattern constructed (using B) by rotating each surface into the top plane about its top edge. An ink tracing is made on transparent cellulose acetate (.015 inch thick), and mineral lineation, distribution pattern, fracture traces, etc. are added from field notes. The acetate is cut, folded, and bonded to form the model.

Orientation of the model on a compass rose provides a means of determining flow structures with a degree of accuracy within limits of error inherent in the original field measurements.

GRAPHIC SOLUTION FOR CERTAIN LINEATION PROBLEMS

KURT E. LOWE

The co-ordinates of linear flow structure can be determined graphically from field measurements provided it is not complicated by the presence of flow layers and the linear elements are minerals possessing prismatic habit with essentially equidimensional cross section (*e.g.*, quartz, hornblende, pyroxene).

The method is based on a simple geometric relationship involving an ideal, cylindrical linear element cut by a plane (= exposure surface). The long axis of the cutting ellipse (= direction of surface lineation) and the cylinder axis (= orientation of linear structure) lie in a plane normal to the cutting plane. Two such normal planes derived from two different cutting planes intersect in the sought axis of the cylinder.

Strike and dip of an exposure surface and pitch of its mineral lineation are measured in the field and plotted on a Schmidt net in the conventional manner. By rotating the net a plane (N) is found which contains both the line of lineation and the plane normal to the surface. This procedure is repeated for at least eight surfaces of different orientation. In the ideal case all resulting N planes intersect in a single line. Actually multiple answers for the linear orientation result, depending on the approach of field conditions to the theoretical ideal. The problem is solved by statistical determination of the arithmetical median from all the possible bearings and plunges arranged in numerical order.

Encouraging results have been obtained by application of this method to the hornblende orientation in the Storm King granite of the Hudson Highlands.

STRUCTURE OF AA LAVA FLOWS*

GORDON A. MACDONALD

Recent geologic literature reveals a common misconception of the structure of aa lava flows. The impression that these flows consist throughout of loose clinker is generally false. Hundreds of aa flows have been examined in cross section in Hawaii, and practically all have a massive phase, generally thicker than the clinker phase. Typically, the massive central part of the flow is both overlain and underlain by layers of clinker. The upper clinker layer is essentially continuous throughout the extent of the aa flow. The lower clinker layer is generally thinner and less continuous than the upper. Locally, layers or irregular masses of clinker occur within the massive phase. Only very rarely and locally is the flow clinker throughout. The margins of recent aa flows exhibit solid banks of clinker, but it is seldom necessary to dig into the bank more than a few feet to expose the massive central phase.

Eleven sections have been measured in the walls of South Halawa, Moanalua, and Waimalu valleys, on Oahu. In individual sections the proportion of clinker to total aa ranges from 15 to 45 per cent. In the shaft of the skimming well at Paauilo, on the northeastern flank of Mauna Kea, on

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Hawaii, a total thickness of 267 feet, all aa, was measured. Twenty complete flow units are exposed, ranging from 4 to 28 feet thick. In individual flow units the proportion of clinker to the total thickness of the unit ranges from 17 to 66 per cent, averaging 39 per cent.

LIMESTONE SOLUTION IN SOUTHEASTERN ALABAMA AND SOUTHWESTERN GEORGIA

F. STEARNS MACNEIL

Within the Tertiary formations of Alabama, a large area of residuum and disarranged beds formed by solution of limestones of Oligocene and upper Jackson (Eocene) age extends as a crescent from central Alabama into Georgia to include the general area mapped as Ocala limestone in Georgia. Its maximum width is about 50 miles in southwestern Georgia. Solution of the Oligocene limestones is much more extensive.

The material is heterogeneous and without bedding. It consists of argillaceous and ferruginous residues from the solution of limestone, chert blocks formed by partial silicification of limestone of both Oligocene and Jackson age, and incorporated masses of Miocene clay and sand and terrace gravels.

The solution area is due to low dip (about 12 feet to the mile at the Chattahoochee River) and high purity of the limestone. The upper part of the Jackson passes eastward from clastic to high carbonate (Ocala) limestone in west-central Alabama and intertongues with thick-bedded clays and marls which protect the limestone tongues from solution in Peach and Macon counties, Georgia.

Cooke (1935) proposed the name Flint River formation for the Oligocene residuum, and the beds were referred to the upper Oligocene on the basis of fossils found in chert accumulations along the Flint River near Bainbridge, Georgia. Unaltered limestone in southernmost Georgia, the upper part of which carried the same fauna was referred to the Suwannee limestone. Recent work has shown, however, that the lower and middle Oligocene are also represented in the Suwannee.

The beds of Oligocene cherts near Bainbridge rest on irregularly dissolved Ocala surfaces, but a few miles north, where solution penetrates to the base of the Ocala, the residuum of the Ocala cannot be separated from the Oligocene. Flint River formation as applied to this residuum is abandoned.

Formation of chert was local and fortuitous, and the present distribution of cherts of different age in no way reflects original areal geology or structure.

ROSICLARE AND AUX VASES SANDSTONES IN SOUTHERN INDIANA

CLYDE A. MALOTT

A thin bed of calcareous sandstone at the base of the Chester series (upper Mississippian) in southern Indiana, known for some years, recently has been traced through the entire outcrop area of the Chester in southern Indiana. It ranges from a few inches to about 12 feet in thickness, is highly calcareous, and much of it is detrital. Locally its place is taken by a thin greenish shale or a sandy shale. It rests upon a bed of brecciated limestone, frequently cherty, a few inches to about 5 feet in thickness, which contains *Platycrinus penicillus* of Ste. Genevieve age. Above it is the Paoli limestone, the first limestone of the Chester, composing the lower part of the Renault as developed in southern Indiana. The sandstone is correlated directly with the Aux Vases sandstone of basal Chester age.

Some 25 to 60 feet below the Aux Vases sandstone is another much cross-bedded and calcareous sandstone of variable thickness up to a known maximum of 38 feet. This Ste. Genevieve sandstone is constant in occurrence. Where massive it is made up of fine-grained quartz, but usually it contains detrital material, mostly of small rounded chert pellets. Well-rounded, frosted, vitreous quartz grains are common, especially in the more limy phases. This sandstone appears to be at the stratigraphic position of the Rosiclare sandstone of southern Illinois and probably should be correlated with it. In Cataract Falls in the bed of Mill Creek in northern Owen County it forms a massive bed 23 feet thick and composes the middle third of the Ste. Genevieve.

POST-PLEISTOCENE DEGLACIATION AND REGLACIATION

FRANÇOIS E. MATTHES

Throughout the middle portion of the post-Pleistocene interval summer temperatures in northern Europe, the northern United States, and adjoining parts of Canada ranged appreciably above those of the present time. That fact is definitely indicated by the stratigraphic succession of different vegetation types in postglacial peat bogs, as determined chiefly by the pollen-analysis method, and is confirmed by several other, independent lines of evidence. During the "climatic optimum" the timberline in the Alps and in Scandinavia lay 1000 to 1400 feet higher than now. The snowline must have lain correspondingly higher. Many glaciers consequently melted away completely, but those that originated at sufficiently high altitudes remained in existence, though greatly reduced in size.

During the ensuing cooler period the snowline sank to its present level and at times somewhat below it. The surviving glaciers re-expanded, and many new ice bodies were born. The climax of this period of reglaciation fell in the seventeenth, eighteenth, and nineteenth centuries, as has been definitely determined in Europe. The glaciers then attained their greatest extension since Pleistocene times, and physiographic evidence indicates that this was probably true also in North America, South America, and New Zealand. The volume of new land ice that was formed may have sufficed to lower sea level 6 feet from the strand lines of the "climatic optimum." In spite of recent wastage the glaciers today still cover a much larger area than they did in that warm period.

GENERAL PRINCIPLES OF ARTIFICIAL GROUND-WATER RECHARGE*

O. E. MEINZER

The natural subterranean reservoirs formed by the porous and permeable rocks differ from surface reservoirs chiefly in that they have complex structure and great internal resistance to the flow of water. Their full utilization requires systematic development based on the geology and hydrology of the aquifer and the principles of hydraulics distinctive of ground water. Recharge may be greatly increased simply by pumping from wells and thus making storage capacity available. However, the rate at which any group of wells can yield water perennially is limited by their ultimate cone of depression with maximum drawdown. Further utilization of the reservoir calls for new wells at adequate distances from the old wells or artificial recharge near them. In some places large supplies have been obtained by locating wells near a stream and developing a steep hydraulic gradient from the stream to the wells.

In an artesian aquifer geologic study with test driling is needed to determine the actual intake area and its structural relations to the pumped wells, as a clay bed, fault, or other barrier may intervene between the assumed intake area and the wells. If the capacity of an artesian aquifer to carry water to the wells under maximum drawdown is less than the potential recharge in the intake area, further utilization can be accomplished only by recharge through wells penetrating the confining bed or by sinking production wells near the intake to steepen the hydraulic gradient.

Artificial recharge requires an effective process for getting the surface water into the saturated part of the aquifer—either by surface infiltration or through wells. The major requirement, in addition to a permeable terrane, is clean water that will not clog the intake, or practicable means of periodically cleaning it. Various processes are now in use with constantly developing technique.

DELINEATION OF PARALLEL FOLDS, AND MEASUREMENT OF STRATIGRAPHIC DIMENSIONS

JOHN B. MERTIE, JR.

The delineation of parallel folds in structural sections, and the extraction therefrom of stratigraphic information, has generally been done with considerable personal interpretation. If structures must

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be drawn, or sections measured, from two structural observations, this is unavoidable; but commonly more than two observations are available, and methods may be applied to minimize the personal equation.

Methods are recommended where more than two structural observations are available, the beds having constant or nearly constant strikes. Parallel curves used to represent sections through parallel folds are necessarily involutes that may be generated from one or more evolutes. It is more practical to derive an evolute, and to construct from it a set of parallel curves, than it is to draw such curves directly. Simple graphical methods are illustrated for the construction of evolutes from different sets of structural data, and for the subsequent construction of parallel curves. An examination of the resulting evolutes and involutes shows that most of them may be represented analytically by the equation $y = ax^n$, if suitable values are assigned to the parameters a and n.

Interpretations and conclusions based upon two structural observations may be 100 per cent or more in error. Nevertheless it often happens that either only two observations are available, or that many observations with highly variable strikes must be utilized in pairs. If the variation in strike is small, the construction of concentric circular arcs is considered satisfactory. When this geometrical method fails, however, recourse is had to an integrated formula for mean strike and dip, by the use of which all stratigraphic dimensions may be computed. Both numerical and graphical solutions of this formula are given.

TERTIARY NAUTILOIDS OF THE AMERICAS

A. K. MILLER

Nautiloid cephalopods are widely distributed in the Tertiary strata of North, Central, and South America and the West Indies. Geographically they range from Alaska to Tierra del Fuego, and stratigraphically they extend throughout all the Tertiary, though they seem to be rare in the Pliocene. Locally they are abundant in the Early Tertiary of southeastern United States and northwestern Peru, but elsewhere they are sporadic.

All have nautiliconic conchs and orthochoanitic siphuncles, and none bears prominent ornamentation. Modern *Nautilus*, which extends back to the Eocene and which is more or less typical of the Tertiary forms, helps us to understand their habits, habitat, anatomy, and shell.

Altogether about 75 species of nautiloids are known from the Tertiary of the Americas (including the West Indies). On the basis of the form of the conch, the position of the siphuncle, and particularly the shape of the sutures, these can be divided into three families: (1) the Nautilidae, which includes *Nautilus* and *Eutrephoceras*; (2) the Hercoglossidae, which includes *Cimomia*, *Hercoglossa*, *Deltoidonautilus*, *Woodringia*, and *Aturoidea*; and (3) the Aturidae, which has only one generic representative, *Aturia*. Half of these genera are not known above the Eocene; but *Eutrephoceras* and *Cimomia* extend up into the Oligocene, *Aturia* ranges up into the Miocene, and *Nautilus* (which is not known to be represented in the American Tertiary) is still extant.

RELATION OF OVERTHRUST FAULTS IN SOUTHWEST VIRGINIA

RALPH L. MILLER

Erosion along the crest of the Powell Valley anticline in Lee County, Virginia, has exposed the Pine Mountain overthrust in a series of fensters. Recent studies in the area of these fensters have furnished new information on the movement of the Cumberland Block, and the drilling of wells for oil in and near the fensters has supplied subsurface data on both the overthrust and the stationary blocks. Formations from Cambrian to Pennsylvanian age are involved in the overthrusting, but nowhere have Lower Cambrian rocks below the Rome formation been found in the overthrust block.

Overthrust faults southeast of the Cumberland Block bring the Rome formation to the surface in numerous places, but neither the pre-Cambrian crystallines nor the Cambrian rocks of pre-Rome age are exposed, although the stratigraphic displacement on some faults is many thousands of feet. The surface rocks of the Appalachian Valley seem to be cut off from the basement rocks by flat-lying overthrusts at or above the base of the Rome, not only beneath the Cumberland Block but also south-

eastward to the Blue Ridge. The faults exposed at the surface are believed to be branches which join the major overthrusts at depth. Whether the Pine Mountain fault extends as one continuous, nearly flat fault beneath the entire width of the Appalachian Valley with other thrust faults branching upward from it, or whether several major flat overthrusts are present beneath the Appalachian Valley is not yet known.

CHARACTER AND ORIGIN OF CERTAIN CLASTIC SEDIMENTS IN THE SOUTHERN APPALACHIANS

BERLEN C. MONEYMAKER

Several thick formations composed entirely of fine to coarse clastic sediments occur in the Southern Appalachians of eastern Tennessee, western North Carolina, and northern Georgia. An enormous thickness of fine to moderately coarse sediments is mapped as Great Smoky conglomerate in the Nantahala quadrangle by Keith, in the Ellijay quadrangle by La Forge and Phalen, and in the intervening Murphy quadrangle by Moneymaker. In the Knoxville quadrangle, the same rocks are mapped as the Cades conglomerate, Thunderhead conglomerate, Hazel slate, and Clingman conglomerate.

Although these rocks have undergone varying degrees of metamorphism and are nearly everywhere highly schistose, original sedimentary characters survive. Stratification is conspicuous, the arenite strata ranging from 2 to 20 feet thick, and the interstratified slate layers from less than an inch to several feet. In areas of intense metamorphism bedding planes are not open but are clearly marked by abrupt changes in materials. The materials are poorly sorted, but there is gradation within beds, from coarse at the bottom to fine at the top. Cross-bedding is rare but has been noted at Hiwassee Dam in North Carolina. The mineral grains are angular, and even the larger pebbles are very poorly rounded.

The arenites are light to dark bluish gray and are composed largely of quartz, biotite, muscovite, potassium feldspar, and plagioclase, but contain numerous other detrital, metamorphic, and secondary minerals. Small to large, sharply angular fragments of black slate occur throughout the formations, and in places the rock is a slate breccia.

Many geologists, including Barrell and Moneymaker, have considered these rocks terrestrial deposits of fluviatile origin. Continued work on this problem has convinced the writer that unweathered sediments were rapidly deposited or "dumped" into a rapidly subsiding geosynclinal basin, closely adjacent to highlands undergoing rapid erosion.

PETROLOGY OF THE NEPHELINE AND CORUNDUM BEARING ROCKS OF SOUTHEASTERN ONTARIO

LOUIS MOYD

Southeastern Ontario is noted for its great variety of unusual rocks and rare minerals. However, there appears to have been no concerted effort to develop a clear and logical picture of the genetic relations of such diverse types as the foliated nepheline- and corundum-bearing rocks, rare-element rich pegmatites, calcite-rich "vein-dikes", dark gneisses, and marbles.

After several years in the field, the author became aware of a distinct pattern. Field evidence indicates that most of the nepheline- and corundum-bearing rocks, among others, are migmatites, formed from pre-existing rocks of the Grenville series. Since many other regions have been invaded by granitic magmas without development of similar migmatites, some factor peculiar to this region must be considered. Paucity of siliceous rocks and superabundance of marbles in the Grenville are believed to provide the key.

Granitic masses were intruded into the silica-poor Grenville terrain. These, for the most part, would crystallize normally, giving rise to usual siliceous pegmatites and emanations and granitizing the gneissic country rocks. However, some of the magma would react with the dolomitic marbles, releasing emanations rich in carbon dioxide. These emanations, while traversing the silica-poor country rocks, would lose much of their silica, forming granitic and syenitic migmatites, and finally, impoverished in silica, would form more unusual migmatites. These mineralizer-rich emanations

could convert the high-lime feldspars of the dark gneisses to alkali feldspars, releasing alumina to form nepheline or corundum, and lime to produce the ubiquitous pockets of calcite, accompanied by fluorite, apatite, sphene, scapolite, and other minerals containing lime in combination with mineralizers.

POST-PALEOZOIC MINERALIZATION IN PENNSYLVANIA

W. M. MYERS

Many scattered instances of metalliferous mineralization are known in Central Pennsylvania. Some of these deposits have been mined and have served as small sources of metal. They have never developed into large producers of commercial significance nor have they been explored extensively. The most common mineralization is galena-sphalerite associated with minor amounts of pyrite and chalcopyrite. The common gangue minerals are calcite and barite. At the outcrop typical oxidation products are found although the depth of oxidation is small, and unaltered sulphides are found close to the surface. Such deposits are well developed in the Ordovician limestones in Sinking Valley, Blair County, and in the Tuscarora sandstone near Bellefonte, Centre County. They occur typically in steeply dipping fractures or fault planes of unknown depth in the immediate vicinity of major faults. In the sandstone the ore minerals have served as a cement which has bonded the angular fragments of country rock producing a breccia. The presence of a thin soil overburden and the absence of open workings have made examination difficult and valuation of possibilities impossible. These veinlike deposits show the common criteria of hydrothermal origin except there are no known igneous rocks in the area. Peridotite dikes, known to be post-Pennsylvanian, have been found in southwestern Pennsylvania intersecting coal strata. Evidence suggests that some Paleozoic sediments have been intruded to an unknown degree by igneous rocks, and processes of differentiation may have supplied solutions that have produced concentrations of metallic sulphides.

LAKE TITICACA OVERTHRUSTS

NORMAN D. NEWELL

A comprehensive reconnaissance study of areal geology of the basin of Lake Titicaca, Peru and Bolivia, occupying approximately a year, reveals extensive overthrusts on the two sides of a neutral axis which approximately bisects the lake. Evidence of compression from the two sides of the lake toward the axis is found in (1) abundant overturned and recumbent folds, in which the axial planes commonly dip away from the axis of the basin at approximately 45° and less; and (2) several regional overthrusts which are opposed on the two sides of Titicaca. In many instances isoclinally folded Cretaceous limestones and gypsiferous shales have been "smeared" over an old peneplain surface on highly competent Devonian quartzites of relatively open structure. Numerous instances were recognized where older rocks (Devonian, Jurassic, Cretaceous) are thrust over an enormous sequence of Tertiary clastics. Overthrusting occurred rather late in the Tertiary, during the last Andean compressional paroxysm, prior to peneplanation of the "Puna" cycle. The hydrographic basin of Lake Titicaca appears to be largely the result of Pliocene or post-Pliocene collapse along great normal faults.

STRUCTURE OF THE LARAMIE RANGE ANORTHOSITE, WYOMING

WALTER H. NEWHOUSE AND ARTHUR F. HAGNER

The Laramie Range pre-Cambrian anorthosite series extends about 30 miles north–south and 10 to 18 miles east–west and includes anorthosite, noritic anorthosite, olivine anorthosite, and feldspathic norite. Anorthosite is bordered by younger gabbro, quartz syenite, and granite. Near the southern part gabbro and granite have split the series in two. The oldest rocks are dolomite, quartzite, and hornblende schist.

The anorthosite series is arranged in crude compositional layers which form map units each several thousand feet thick. Structural features are relatively simple and are outlined by compositional layering and by a marked parallelism of plagioclase crystals (platy crystal structure). The major

structure is a sharply defined anticline in the eastern part which trends N.–S. for 25 miles. This structure, or perhaps another anticline, continues in the southern anorthosite. Platy crystal structure and layering are parallel in individual outcrops, but larger relations on certain parts of the major anticline are not parallel.

The region displays a close relation of lithology to structural features produced during folding. Feldspathic norite and olivine anorthosite are associated with folds in the anorthosite layers. A zone of granulated light-gray anorthosite 1000–3000 feet wide and approximately 9 miles long is present along or near the anticlinal crest in the vicinity of the domal part. A fractured and altered zone nearly 8 miles long forms a southern continuation of the granulated zone. The fracture zone received a mineralization of widely disseminated olivine with local magnetite-ilmenite. Later intrusion of abundant small granite dikes produced widespread alteration.

EARTHQUAKE HISTORY OF CENTRAL NEW MEXICO

STUART A. NORTHROP

About 94 per cent of New Mexico's earthquakes have originated in a narrow belt along the Rio Grande between Socorro and Albuquerque; the majority have been concentrated in the southern half of this 75-mile belt. A study of available noninstrumental information, including old newspaper files, reveals that 542 shocks have been recorded in 23 different years between 1868 and 1945. Maps, tables, and frequency charts have been prepared.

Notable features include: (1) occurrence in swarms (daily for 3 weeks in 1935, daily for 3 months in 1893, daily for 6 months in 1906); (2) maximum nocturnal frequency; (3) maximum annual frequency (82 per cent) in the July–December period; (4) numerous strong to moderately strong shocks (10 of Rossi-Forel intensity VIII, 15 of VII, 27 of VI, 33 of V); (5) fairly large areas affected by several of the shocks; and (6) occasional property damage, but no loss of life.

This seismic belt lies in a narrow strip of the Basin and Range province which extends northward between the Colorado Plateaus and the Great Plains and is essentially a broad arch with a complex graben—the Rio Grande Depression—developed along its crest. Thick Cenozoic basin deposits occupy the Depression. These, as well as older rocks on either side, are cut by numerous late Cenozoic faults. It is suggested that the seismicity is chiefly the result of tectonic adjustments among fault blocks beneath, and possibly to some extent within, the Cenozoic alluvium.

LARGE *SCHIZOPHORIA* IN BASAL PENNSYLVANIAN OF NEW MEXICO*

STUART A. NORTHROP AND GORDON H. WOOD, JR.

A unique fauna characterized by an abundance of large *Schizophoria* was first discovered by the junior author at one locality and later by the senior author at another locality, both in north-central New Mexico, between the Nacimiento Mountains and the Jemez Plateau, about 45 miles north of Albuquerque. The fauna occurs in a thin zone near the base of the Sandia formation only a few feet above the pre-Cambrian. The original discovery was made on the east wall of Guadalupe Canyon, Cañon de San Diego Grant, about 5 miles above Cañon Landing; the second locality is about 2.2 miles southwest of the first, high on the west wall of Guadalupe Canyon.

The fauna includes worm(?) impressions in brachiopod shells, *Aulopora* sp., crinoid fragments (common), echinoid spine, several genera of bryozoans (abundant), *Composita* sp., *Derbyia* sp., *Dictyoclostus* cf. *hermosanus* (common), *Hustedia* sp., *Schizophoria* sp. (abundant), *Spirifer occidentalis* (common), and a shark tooth.

The *Schizophoria*, which is easily the most striking element of the fauna, is closely related to *Schizophoria oklahomae* Dunbar and Condra from the Wapanucka and Morrow formations of Oklahoma. The species is represented by a few complete specimens, a few dorsal valves, and several dozen ventral valves. A notable feature is its large size; many of the ventral valves exceed 50 mm. in width, and the largest dorsal valve is 73 mm. long, 73 mm. wide, and 25 mm. thick. Impressions of the pallial sinuses are strongly developed.

We have not seen this *Schizophoria* elsewhere in the Pennsylvanian of New Mexico.

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STUDIES OF MINERAL SULPHO-SALTS: XI—WITTICHENITE (KLAPROTHITE)

E. W. NUFFIELD

Wittichenite and klaprothite were undistinguished under the name Kupferwismutherz, later wittichenite, until Petersen (1868–1869) restricted wittichenite to the mineral with the composition $3Cu_2S \cdot Bi_2S_3$ and proposed klaprothite for a mineral resembling emplectite ($Cu_2S \cdot Bi_2S_3$) which gave a composition near $3Cu_2S \cdot 2Bi_2S_3$. X-ray examination of numerous specimens labelled wittichenite or klaprothite from the Wittichen mines, Baden, gave only wittichenite and emplectite. The wittichenite pattern is identical with that given by the homogeneous fusion product $3Cu_2S \cdot Bi_2S_3$. A crystal, part of which gave the wittichenite pattern, yielded the orthorhombic unit cell with $a = 7.66$, $b = 10.31$, $c = 6.69$ kX; space group $P2_12_12_1$; contents $2[3Cu_2S \cdot Bi_2S_3]$. Many published observations on "klaprothite" evidently refer to wittichenite, and it appears that Petersen's analysed "klaprothite" was a mixture of wittichenite and emplectite.

OROGENY OF THE MEXICAN PLATEAU AND ITS RELATION TO ORE, OIL, AND GROUND WATER*

S. SPENCER NYE

Investigation of the alluvial basins near Torreon indicate that (1) the basins were produced by two major periods of downfaulting and subsequent filling, and (2) previous interpretations of the structural and geomorphic relations of the Jurassic-Cretaceous strata as the product of regional compressive forces, followed by (a) erosion of once-continuous folds, or by (b) simple blockfaulting at a much later date, do not accord with Newton's Laws of Motion.

The following hypothesis is proposed: (1) The plateau was uplifted (largely during mid-Tertiary) by expansive forces resulting from continuous heating of magma beneath it. (2) Lavas (now forming Sierra Madre Occidental) were extruded during and following uplift. (3) The extrusions resulted in release of pressure within the magma chamber, structural failure of the roof, and collapse of the basins. (4) The deformation of the Jurassic-Cretaceous strata along the east edge (Sierra Madre Oriental) and within the plateau was accomplished (a) by faulting (step and block faulting along edge, differential block faulting within) of a pre-Jurassic basement during and following uplift and extrusions, and (b) by movements by gravity of sheetlike masses of these strata, controlled by the configuration of the basement during and following the faulting. (5) Ore deposition occurred in openings formed during uplift and during first and second major periods of downfaulting. (6) Mild deformation on coastal plain permitted oil accumulation. Intense deformation within plateau destroyed oil structures. (7) Fracturing of the Jurassic-Cretaceous strata provided reservoir and channel openings for the large springs. Generally, aquifers in first fill are scarce and poor, those in second fill are numerous and good.

GENERAL STRATIGRAPHY OF THE EAST TENNESSEE ZINC DEPOSITS

CHARLES R. ODER AND H. W. MILLER

Zinc deposits occur in nearly every county in East Tenessee in Cambrian and Ordovician rocks.

Ore has been produced from the Shady, Rome, Maynardville, Copper Ridge, and Kingsport formations.

The Shady dolomite has yielded "carbonate" ore at Embreeville. It is composed of 1000 feet of light-gray, coarsely crystalline dolomite and dark-gray, fine-grained dolomite and limestone.

The Rome formation includes about 1000 feet of variegated shales and red sandstones. Sphalerite sometimes occurs in thin calcareous zones in the upper shales.

The Maynardville limestone contains 60 to 250 feet of dark-gray, fine-grained limestone and dolomite some of which shows argillaceous laminae.

The Copper Ridge formation usually consists of 900 to 1200 feet of dark sugary and light-gray, fine-grained, cherty dolomite with considerable limestone in the eastern areas.

Stratigraphic studies have proved valuable in the important Mascot-Jefferson City mining dis-

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trict. The following divisions of the Kingsport formation have been described, in descending order: (1) 101 to 135 feet of light- and dark-gray dolomite with a little limestone and numerous arenaceous and cherty horizons, (2) 44 to 50 feet of very light-gray dolomite with concentric chert nodules, (3) 33 to 38 feet of light- and dark-gray dolomite and a little limestone, sometimes altered to crystalline dolomite, (4) 178 to 216 feet of brown limestone, frequently altered to crystalline dolomite, a moderate amount of light- and dark-gray dolomite, and numerous cherts.

Some crystalline dolomites in the Kingsport are believed to represent replacement of limestone.

NOTES ON THE STRUCTURE OF DELAFOSSITE

A. PABST

In a previous report (1938) it was shown that delafossite probably has the same structure as artificial $CuFeO_2$. The density corresponding to this structure, 5.52, agrees closely with the best measured value 5.41, reported in the seventh edition of Dana's *System of mineralogy*.

Published accounts of powder patterns of delafossite cannot be fully reconciled with the requirements of the structure. It is recommended that even patterns intended only for identification should be indexed and checked against the literature.

The valence state of copper and iron in delafossite has been considered by Rogers (1913). From a consideration of the intensities of powder-diffraction lines it is possible to choose rather closely the single parameter of the delafossite structure. This determines the interionic distances Cu-O and Fe-O. From these one can conclude as to the valence state of the copper and iron by comparison with corresponding interionic distances in other compounds of these metals. Such a comparison leads to the conclusion that delafossite is cuprous metaferrite, $Cu'Fe'''O_2$, as surmised by Rogers.

It is shown that it is a matter of indifference whether ionic or atomic f values are used in making the necessary intensity calculations since the calculated intensities vary much more with moderate changes in interionic distance than with change in the scattering power of the ions.

It is also shown that certain ambiguities still remain in the structure of delafossite. These cannot be relieved by the study of powder patterns alone which do not allow the discrimination of a parameter x from $\frac{1}{3}$-x.

CONTACT-METAMORPHIC DEPOSITS OF CASSITERITE IN CALIFORNIA*

LINCOLN R. PAGE

Small quantities of cassiterite have been produced at the Evening Star mine in the Cima district, San Bernardino County, and from the Meeke mine in the Gorman district, Kern County, California. These deposits are of the contact-metamorphic type and were investigated by the Geological Survey in 1940–1944.

The Evening Star deposit is in dolomite and dolomitic marbles near an intrusive body of quartz monzonite. Cassiterite occurs with scheelite, chalcopyrite, sphalerite, pyrite, and magnetite as disseminated grains, euhedral crystals, and massive aggregates in tremolite-serpentine-calcite rock. Near the surface hematite, limonite, malachite, chrysocolla, melaconite, calamine, and other secondary zinc minerals are common. Talc is associated with brecciated cassiterite along shear zones that cut the ore.

The irregular, lenticular ore bodies of the Evening Star deposit were formed by replacement of favorable beds along and outward from a mineralized zone 120 feet long and up to 20 feet wide.

In the Gorman district cassiterite has been identified in six small, irregular bodies of iron-rich tactite and limonitic gossan that occur in recrystallized limestone at the margin of a granite intrusive. The primary ore contains cassiterite, scheelite, powellite, pyrite, chalcopyrite, arsenopyrite, molybdenite, magnetite, epidote, tourmaline, ludwigite, amphibole, garnet, phlogopite, calcite, and quartz, though not all these minerals occur in each deposit. The gossanin deposits such as the Meeke also contain malachite, chrysocolla, jarosite, gypsum, chalcedony, opal, cuprite, native copper, and clay minerals.

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STRUCTURAL AND MINERALOGICAL CHARACTERISTICS OF SOUTH DAKOTA PEGMATITES*

LINCOLN R. PAGE

Detailed structural and economic investigations of over 140 South Dakota pegmatites by members of the Geological Survey in 1939–1945 have shown that many of the pegmatites exhibit similar structural and mineralogical characteristics. These characteristics have a direct bearing on the origin of pegmatites as well as on mining practice.

The important structural features of these pegmatites are (1) external shape, (2) zoning, (3) gneissic banding, (4) orientation of minerals, and (5) internal cross structures. These structural features show a definite relation to the planar and linear structures of the wall rocks. In most pegmatites concentrations of minerals can be related to these structures.

The distribution of minerals in all the pegmatites studied seems to follow a general sequence related to the internal zoning, but the abundance of any particular mineral is controlled by the composition of the liquid from which the pegmatite formed, and by the history of crystallization. Variations in the chemical composition of plagioclase, beryl, and columbite-tantalite have been noted in different parts of a pegmatite and appear to be systematic when related to zonal structure. These variations in chemical composition may be accompanied by differences in physical form and color. The alteration of spodumene and the consequent decrease in lithia content appear to be related to its structural position in a pegmatite. Preliminary investigations suggest that perthite and microcline, as well as flat and "A" books of muscovite also have a preferred structural position.

CLINOCLASITE

CHARLES PALACHE AND L. G. BERRY

Clinoclasite, $Cu_3AsO_4(OH)_3$, is described from a new locality, Majuba Hill, Nevada, from Cornwall, and from Utah, with complete revision of its morphology. Monoclinic; prismatic—$P2_1/a$. $a:b:c = 1.9109:1:1.1223$, $\beta = 99°22'$; $p_0:q_0:r_0 = 0.5873:1.1073:1$, $\mu = 80°38'$; $a_0 = 12.36$, $b_0 = 6.45$, $c_0 = 7.23$ Å, $\beta = 99°30'$. Forms: c(001), a(100), m(100), g($\bar{2}$01), o(111), q($\bar{1}$11) and others less certain. The relations of the new elements to those hitherto used are explained. There are 4 units of the formula given above in the unit cell. An x-ray powder spectrum is given.

INVESTIGATION IN PETROGRAPHIC METHODS OF COAL ANALYSIS†

BRYAN C. PARKS AND GILBERT H. CADY

Analysis of columns of bituminous coal to determine composition of banded ingredient is a rather common routine in some laboratories. However, such analyses restricted to complete bed coal samples, fairly difficult to secure, give information more fundamental than utilitarian. General usefulness of petrographic methods of banded ingredient analysis requires application to broken coal of commercial sizes. The technique developed and used by the Illinois Geological Survey and the results obtained are described. These results are supported by four preliminary or concurrent accomplishments:

(1) Development of a crushing technique using roll crushers to separate the banded ingredients into discrete particles predominately of megascopic size range.

(2) Development of size-distribution curves for ascertaining distribution of banded ingredients in fine sizes extremely difficult to analyze megascopically.

(3) Determination that microvitrain from clarain contributed but little to the quantity of analytical vitrain when the approved sample-preparation methods were used.

(4) Determination that under commercial methods of coal preparation response of banded ingredients to changes in density of gravity-separation fluids was small.

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† Presented with the consent of M. M. Leighton, Chief, Illinois Geological Survey.

GNOMONIC AND LINEAR HEPTAXIAL TWO-CIRCLE CALCULATION

A. L. PARSONS

Referring a hexagonal crystal to three sets of orthorhombic axes and taking $\varphi(1-3)$ and $\varphi'(1-3)$ $(=90°-\varphi)$ alternatively, gnomonic calculation yields the following:

$\cos \varphi_{1-3}(\text{or } \varphi'_{1-3}) \cdot \tan \rho =$

$$\frac{h\cdot c}{1a} : \frac{(h+2k)c}{1\sqrt{3a}} : \frac{(h+k)c}{1a} : \frac{(2h+k)c}{1\sqrt{3a}} : \frac{h\cdot c}{1a} : \frac{(h-k)c}{1\sqrt{3a}}$$

Linear calculation yields the following:

$\tan (90° - \rho)/\cos \varphi_{(1-3)}$ (or φ'_{1-3}) =

$$\frac{1\cdot a}{kc} : \frac{1}{h+2k} \cdot \frac{\sqrt{3a}}{c} : \frac{1}{h+k} \cdot \frac{a}{c} : \frac{1}{2h+k} \cdot \frac{\sqrt{3a}}{c} : \frac{1\cdot a}{hc} : \frac{1}{h-k} \cdot \frac{\sqrt{3a}}{c}$$

The linear constants are a/c and $\sqrt{3a}/c$, and the reciprocal gnomonic polar constants are c/a and $c/\sqrt{3a}$, which, as they may be interchangeable, might be indicated as p_0 and π_0. The gnomonic polar representation of the facts shown in the linear projection of a face $(h\,k\,\bar{i}\,l)$ is a circle with $\tan \rho$ as diameter, which is used for the graphical determination of the polar constants. The linear projection is shown to be well adapted for use in two-circle calculation. Goldschmidt's p_0 and π_0, $p_0(G_1)$, and $p_0(G_2)$, play no part in the calculation of polar constants; $p_0(G_1)$, however, is the basal edge of an orthorhombic prism with axes, $c:c/\sqrt{3}:r_0(=1)$.

The calculation of the reciprocal (polar) constants depends on two sets of triangles (not polar) which are homopolar, with one common angle, and with the sides adjacent to this angle having reciprocal tangents, a problem for plane trigonometry.

MELONITE FROM QUEBEC AND CRYSTAL STRUCTURE OF $NiTe_2$

M. A. PEACOCK AND R. M. THOMPSON

Melonite is associated with tellurides, sulphides, and gold, in rich ore from the Robb-Montbray mines, Montbray Township, Abitibi County, Quebec. The mineral is structurally identical with $NiTe_2$ obtained by fusing the elements in vacuum, and x-ray-powder photographs lead to the following structure (C6-type): hexagonal; space-group D_{3d}^3–$C\bar{3}m$ (ditrigonal scalenohedral class—$\bar{3}\,2/m$) $a = 3.835$, $c = 5.255$ kX; cell content $NiTe_2$, giving the calculated specific gravity 7.73, measured 7.72 (Hillebrand); Ni at 000, 2Te at $\frac{1}{3}\,\frac{2}{3}z$, $\frac{2}{3}\,\frac{1}{3}\bar{z}$, with $z = 0.250 \pm 0.005$. The distances Ni-Te = 2.58, Te-Te = 3.44 kX agree with the sums of the appropriate predicted radii of Pauling. The previously published x-ray-powder data for melonite include lines due to free gold. Melonite would be approriately attached to the molybdenite group in systematic mineralogy.

MONTBRAYITE, A NEW GOLD TELLURIDE

M. A. PEACOCK AND R. M. THOMPSON

Triclinic; $a = 12.08$, $b = 13.43$, $c = 10.78$ kX, $\alpha = 104° 30\frac{1}{2}'$, $\beta = 97° 34\frac{1}{2}'$, $\Delta = 107° 53\frac{1}{2}'$; cleavages $(1\bar{1}0)$, $(0\bar{1}1)$, $(1\bar{1}1)$; $(0\bar{1}1):(1\bar{1}1) = 41° 20'$, $(1\bar{1}1):(1\bar{1}0) = 46° 45'$, $(1\bar{1}0):(0\bar{1}1) = 69° 31'$. Cleavages perfect but difficult. Fracture flat conchoidal. Very brittle. Hardness $2\frac{1}{2}$. Specific gravity 9.94. Luster metallic. Color tin-white to palest yellow. Polished sections white, moderately anisotropic, and homogeneous except for sparse ovoid inclusions of intergrown tellurbismuth and altaite. Analysis by Williams: Au 44.32, Te 49.80, Bi 2.81, Pb 1.61, Sb 0.90, Ag 0.55, Fe trace; total 99.99. Cell content, after withdrawing Bi as Bi_2Te_3, Pb as PbTe: $(Au, Sb, Ag)_{24}Te_{37}$ or nearly $12[Au_2Te_3]$. Occurs with gold, tellurbismuth, altaite, petzite, melonite, chalcopyrite, pyrite, sphalerite, chalcocite, and marcasite, in the Robb-Montbray mine, Montbray Township, Abitibi County, Quebec, Canada.

BLOCK FIELDS IN PENNSYLVANIA

LOUIS C. PELTIER

Block fields and boulder-strewn slopes occur throughout the mountains of Pennsylvania south of the limit of Wisconsin glacial drift. Block fields on Bald Eagle Mountain near Montoursville, Blue Rocks near Lenhartsville, and Ringing Rocks near Kintnersville were studied.

The block fields have resulted from an accelerated attack upon rock outcrops on the slopes by frost, movement, and concentration of blocks down slopes, accompanied and succeeded by washing-out of the interstitial fine material. Stabilization of the slopes and weathering of the blocks under temperate conditions then ensued.

Because one of the blockfields rests on the eroded surface of Illinoian till, it appears that all are post-Illinoian, and as all are being disintegrated by present-day weathering they are pre-Recent. They represent: (1) a periglacial arctic climate of Wisconsin date; (2) a gradation into the humid temperate climate of the present day.

HYDROTHERMAL ALTERATION IN THE CASTLE DOME COPPER DEPOSIT*

N. P. PETERSON, C. M. GILBERT, AND G. L. QUICK

The Castle Dome copper deposit, near Miami, Arizona, is in quartz monzonite much older than the mineralization. It is of the low-grade "porphyry" type in which the protore contained about 0.3 per cent copper present as chalcopyrite. The chalcopyrite is associated with a set of narrow, closely spaced, generally parallel quartz-pyrite veins and occurs both within the veins and disseminated in the wall rock.

Hydrothermal alteration of the quartz monzonite consists of three phases. Very weak propylitic alteration of biotite and plagioclase occurs in the marginal part of the mineralized area. Where mineralization is stronger most of the plagioclase and a little orthoclase and biotite are replaced by allophane and a montmorillonite-type clay resembling beidellite. The general appearance of the quartz monzonite is little changed by this clay alteration. The third phase is localized along the quartz-pyrite veins where the wall rock commonly as much as an inch from the vein is replaced by quartz and sericite. In contrast to the localization of the quartz-sericite alteration along veins, the clay alteration is general and can be seen between veins wherever the rock is not completely sericitized. Thus these two types of alteration cannot be separated areally. The most intense clay alteration together with moderate quartz-sericite alteration occurs in the ore body, whereas the strongest quartz-sericite alteration, where pyrite veins are largest and most numerous, is in a zone along the north side of the ore body.

REDUCTION OF SULPHATES IN OIL-FIELD SALT WATER

F. B. PLUMMER

Bastin and others have demonstrated the presence of sulphate-reducing bacteria in oil wells producing salt water. Analyses show that, at 125° F., bacteria alone reduce sulphates in east Texas salt water by 3 per cent in 30 days, forming principally hydrogen sulphide and sodium and calcium hydroxide. The hydrogen sulphide reacts with soluble iron compounds to produce iron sulphide in the absence of oxygen and ferric hydroxide where oxygen or air is present. Where iron or other metals and iron sulphide are already in the water containing the bacteria, the reduction of the sulphates is complete in 30 days or less; where magnesium is present, reduction is complete in 15 days. The effects of changes in temperature, of different metallic substances, of different bactericides, and of concentration of bactericides on sulphate reduction are described and illustrated by tables and curves. The significance of sulphate reduction on corrosive properties of oil-field water, on the forming of sediments, and on certain geologic processes, and especially the part played by bacteria in the formation of concretions, are discussed briefly.

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FORMATION OF TRAVERTINE FROM SPRING WATER IN CENTRAL TEXAS

F. B. PLUMMER

A detailed investigation of the formation of travertine from spring water, both in the field and laboratory, indicates that aeration of the water through agitation by waterfalls and through thin spreading of water over stones, branches, leaves, grass, and other objects is the principal process by which rapid precipitation of calcium carbonate takes place. Blue-green algae, long ascribed the principal role in lime precipitation, play little more part in the process than grass. Some algae, however, do help to fix the calcium carbonate by a sticky film on their surfaces, and in this way they do aid somewhat in the formation of travertine dams and travertine falls. The effect of temperature, the effects of nitrogen, carbon dioxide, and oxygen, and the effect of algae, mosses, grasses, and other plants are described. The distance travelled by the water before deposition of calcium carbonate and the location of the travertine deposits with respect to springs are illustrated. The origin of different types of travertine, such as banded and spherulitic, is discussed. The fact that during late Pleistocene times travertine formed in larger quantities than today is demonstrated. The cause is ascribed to greater rainfall and therefore to more water in springs. It is concluded also that, during the epoch of greatest travertine formation, temperatures must have been as high or higher than they are today.

LOWER PENNSYLVANIAN FORAMINIFERA IN THE COLORADO RIVER SECTION, TEXAS

HELEN JEANNE PLUMMER

Many samples of shale and marls from the Marble Falls and Smithwick formations outcropping in the Colorado River valley, central Texas, have yielded small faunas of Foraminifera (excluding fusulinids), which in some exposures are fairly abundant and well preserved. High compaction of the sediments has contributed to deformation and compression of most tests, so that an understanding of the consistent specific characters of many of the forms has required large suites of specimens. The highly calcareous Marble Falls formation, composed largely of limestones with a few soft marls, has yielded five rather rare adventitious species (one new and restricted to the formation), seven calcareous species (a new and restricted), one calcareous new subspecies (restricted), and one calcareous species not specifically designated. The noncalcareous Smithwick shales have yielded 17 adventitious species (6 new), three of which occur also in the underlying Marble Falls formation. Two new genera have been recognized. The two very different assemblages in the Marble Falls and Smithwick formations are typical of the two very different types of lithology that characterize the formations. Most of the Marble Falls species occur also in the calcareous zones of the middle and upper Pennsylvanian in Texas, and most of the Smithwick species are common in the noncalcareous or only slightly calcareous strata of this overlying sequence.

EXPERIMENTS IN X-RAY IRRADIATION OF GEM STONES

F. H. POUGH AND T. H. ROGERS

The alteration of color in minerals as the result of irradiation by various rays of wave lengths shorter than those of visible light is a well-known phenomenon. However, previous experiments have been but casually mentioned in the literature, and the possibility has not been recognized in many minerals because of the slowness with which the alteration takes place with ordinary radiators. The perfection by the Machlett Laboratories of a new and concentrated beam x-ray tube, with a beryllium window transparent to a wide spectrum, suggested the possibility of performing some experiments which might lead to results observable in a matter of minutes, rather than hours or days. A large series of gem stones were tested, with the expected results in some cases and unanticipated changes in others. The most notable was the golden discoloration of white and pale-yellow sapphires. None of the effects appear to be permanent; all of the colors revert to the original in a short time, either with exposure to ordinary light or upon the application of a low degree of heat. The preliminary study suggests further steps which might be tried, and some possible economic applications.

WHITE RIVER FORMATION OF NORTH DAKOTA*

WILLIAM E. POWERS

During 1945 a careful restudy was made of all known areas of the White River formation in North Dakota. A comparison of detailed sections indicates that the Chalky Buttes stratigraphy is most complete and probably should be used as a standard section for all White River areas in the State. Scarcity of fossils renders exact correlations difficult. Chalky Buttes show a lower unit characterized by coarse sands and gravels (*Titanotherium* beds), a middle unit of marls and chalky limestones (*Oreodon* beds), and an upper unit of greenish sands (*Protoceras* beds). At Cosgrove, Antelope, Young Mans, and Lefor buttes, hard limestones and marls suggest correlation with the middle division at Chalky Buttes. In the Killdeer Mountains, fine calcareous sandstones and marly sands, overlying noncalcareous sands, suggest respectively the middle and lower divisions at Chalky Buttes. Sentinel and Flattop buttes have limestone and marl overlying massive green sandstone. The latter appears to belong to the lower division at Chalky Buttes, and the marl and limestone to the middle. At Blue, Black, and Bullion buttes, massive greenish sandstones overlie Tongue River or other strata below the White River. These green sands probably belong in the lowest division at Chalky Buttes. East and West Rainy Buttes have an upper green sandstone unit bearing vertebrate remains, over marls, over green sandstone. These three units suggest the three divisions at Chalky Buttes. In Little Badlands the stratigraphy corresponds to that at Chalky Buttes.

ALGAE REEFS IN CAP ROCK OF OGALLALA FORMATION ON LLANO ESTACADO PLATEAU

W. ARMSTRONG PRICE, MAXIM K. ELIAS AND JOHN C. FRYE

Discovery in the Ogallala cap rock of this plateau of reef bodies similar to those previously described by Elias from a limestone in the same position in Kansas and elsewhere on the Northern High Plains is announced.

The characteristic concretionary structure of the reefs is widely, but not universally, repeated in the upper part of the Ogallala cap rock and in post-Ogallala limestone cap rocks of basin deposits of the plateau and of pedimentlike slopes between the plateau and Pecos River.

A syngenetic origin for the concretions is preferred to the formerly advanced post-depositional hypothesis of Price.

THE CRYSTAL STRUCTURE OF α-SIC TYPE V.

LEWIS S. RAMSDELL

α-SiC, type V, originally discovered by Ott, has a rhombohedral unit cell, space group $R3m$, with $Z = 17$. Referred to hexagonal axes, $a_0 = 3.073$Å, $c_0 = 128.15$Å, $Z = 51$. Even with simplifying assumptions based on known types, the number of geometrically possible structures is large. However, by means of an extrapolation of what appears to be a definite series in the known types, a structure is predicted which agrees with the observed data with high precision. This structure is as follows:

Hexagonal unit cell—

17 Si atoms at 000, 00 $2z$, 00 $6z$, 00 $8z$, 00 $12z$, 00 $14z$, 00 $18z$, 00 $21z$, 00 $24z$, 00 $27z$, 00 $30z$, 00 $33z$, 00 $37z$, 00 $39z$, 00 $43z$, 00 $45z$, 00 $49z$.

17 C atoms at 00p, 00 $6z + p$, 00 $8z + p$, 00 $12z + p$, 00 $14z + p$, 00 $18z + p$, 00 $21z + p$, 00 $24z + p$, 00 $27z + p$, 00 $30z + p$, 00 $33z + p$, 00 $37z + p$, 00 $39z + p$, 00 $43z + p$, 00 $45z + p$, 00 $49z + p$.

17 Si and 17 C at $\frac{2}{3}$, $\frac{1}{3}$, $\frac{1}{3}$ + the above coordinates.

17 Si and 17 C at $\frac{1}{3}$, $\frac{2}{3}$, $\frac{2}{3}$ + the above coordinates.

$z = 1/51$; $p = 1/68$.

Certain unifying principles covering all seven known types of SiC are evident, and there seems to be no reason why additional types, both hexagonal and rhombohedral, may not be found.

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* By permission of the State Geologist of North Dakota.

DEEP WELLS ALONG THE ATLANTIC COAST

HORACE G. RICHARDS

Logs and samples from 190 wells along the Atlantic Coastal Plain between New Jersey and Georgia have been studied. Samples from several oil tests in Georgia, North Carolina, and Maryland, as well as numerous water wells in New Jersey, Delaware, Maryland, Virginia, and North Carolina, provide the bases for a series of cross sections. (Geological Society project.)

SAUCONITE—THE ZINC CLAY MINERAL

CLARENCE S. ROSS

Zinc clay materials, commonly called tallow clays, have been found to include hemimorphite-bearing clays and zincian montmorillonite, but the characteristic member of the group is a definite zinc mineral analagous to saponite. Comparison of sample from three regions with type sauconite from Friedensville, Pennsylvania, shows that all are similar. Therefore the validity of the name sauconite for a definite zinc clay mineral has been verified.

MILITARY WATER SUPPLY

A. NELSON SAYRE

The trained ground-water geologist can render important service to the armed forces by providing water-supply intelligence for planning on the operational and on the strategic level and by acting as field adviser to the Engineer troops charged with supplying water.

The importance of these services varies somewhat with local conditions, the nature of the operation, the training of the Engineer troops, and other factors. Combat operations usually require ½ gallon to 5 gallons of water per capita per day. In humid regions, this quantity of water is ordinarily obtained from streams, although in some places it necessitates hauling water long distances over roads that are already overcrowded. However, such practices are at times unavoidable under field conditions.

In arid regions or in humid regions where large supplies are required for hospitals and other base installations, securing adequate, safe water supplies is a difficult problem and often requires considerable skill and special equipment and material. Therefore the planning staffs must have the best information possible well in advance of the proposed operation. The geologist assembles and evaluates all the available engineering and geologic data, studies operational photography to determine the nature of the soil and underlying rocks and their relation to water supply as revealed by topography, drainage rock outcrops, etc. He is thus enabled to furnish surprisingly accurate water supply intelligence for consideration in planning.

He can also be helpful as a consultant to the construction engineers during the operations by locating well sites, evaluating springs and stream supplies, and by advising or instructing troops on methods of well construction, development, and pumping.

GLACIAL PEAT DEPOSIT NEAR PITTSBURGH*

JAMES M. SCHOPF AND AUREAL T. CROSS

A deposit of peat associated with lacustrine sediments of glacial age has recently been exposed a few feet above the Pittsburgh coal bed. It is tentatively regarded as correlative with an early Wisconsin glacial stage. The associated strata are described, and the character of the peat indicated by botanical, petrologic, and chemical criteria.

If the suggested geologic age of the peat is correct its antiquity may be on the order of 50,000 or 60,000 years. The age of the Pittsburgh coal bed beneath it is estimated in terms of years at about 250 millions. Accordingly the coal is 4 or 5 thousand times as old as the peat in this deposit, and some comparisons regarding the influence of age on coalification are possible.

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* Presented with permission of the Director, U. S. Bureau of Mines.

GROSS PETROLOGY OF COAL IN RELATION TO EXPLORATION OF COAL RESERVES BY DIAMOND DRILLING*

JAMES M. SCHOPF AND HENRY L. SMITH

Methods evolved in dealing with coal cores in the petrographic laboratory of the Bureau of Mines are discussed. Approximately 2000 feet of selected segments of cores consisting predominantly of coal has been studied in connection with explorational drilling of strategic coal reserves during the war.

A major objective of this work has been to provide a reasonably detailed factual record of the character and variation in coal recovered by drilling. This information has proved of considerable value since it serves to co-ordinate data based on field operations with laboratory analyses and tests. Selection of samples according to appropriate lithologic subdivisions in the coal and the rejection of proper classes of impurities is particularly important.

Frequently there is a marked contrast in the observable lithologic features of the coal due solely to the difference between field and laboratory conditions. Megascopic petrology as readily determined in the laboratory is of practical significance and is supplementary to more detailed observations dependent or the microscope. Data obtained from certain coal cores are used for practical illustration of the methods.

PLANT MICROFOSSIL INVESTIGATIONS IN WESTERN COALS—A PROGRESS REPORT*

JAMES M. SCHOPF AND AUREAL T. CROSS

Plant microfossils provide a means of effectively supplementing other sources of geologic information regarding the precise local identity of coal beds. Studies are being carried on in the Kemmerer coal field in Wyoming, the Paonia district in Colorado, and in the Coos Bay coal field in southwestern Oregon. The present paper indicates the variety of microfossil material available from these Cretaceous and early Tertiary coal deposits, and the practical problems that have bearing on the conduct of such work.

GEOLOGIC HISTORY OF THE BISON IN THE GREAT PLAINS REGION

C. BERTRAND SCHULTZ AND WELDON D. FRANKFORTER

Knowledge of the stratigraphic distribution of fossil bison has been augmented greatly by recent geologic and physiographic work in the Great Plains region.

The bison appears to have first reached the Great Plains shortly before the middle of the Pleistocene. The earliest migrants were giant bison similar to *Bison* (*Superbison*) *latifrons* (Harlan). Remains attributed to these large forms appear in the Grand Island (= Kansan) formation. A somewhat smaller species near the size of *Bison* (*Superbison*) *ferox* Marsh is reported from Upland (= Yarmouth) sediments.

In the "*Citellus* zone" soil (= Sangamon) of Nebraska the bison remains can be referred to a still smaller form which is slightly larger than typical *Bison antiquus* Leidy. A late Pleistocene terrace (= Wisconsin) contains the bones of smaller forms of bison near the size of *Bison antiquus* Leidy. These last remains are frequently associated with Folsom and Yuma artifacts. In subsequent or recent terraces and deposits all the bison remains are referable to the modern species *Bison bison* Linneaus.

The definite diminishing size of the bison from the giant long-horned forms of the middle Pleistocene to the short-horned modern bison is significant. Either the change from large to small is an example of retrogression in the development of the bison, or the different sizes represent separate migrations from Asia. There is little if any evidence to substantiate the latter possibility.

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* Presented with permission of the Director, U. S. Bureau of Mines.

HYDROTHERMAL ALTERATION IN THE SAN MANUEL COPPER DEPOSIT, ARIZONA*

GEORGE M. SCHWARTZ

The San Manuel Copper Exploration is about a mile south of Tiger and 35 miles southeast of the copper deposit at Ray, Arizona. The mineralized rock is principally pre-Cambrian quartz monzonite (Oracle granite) and presumably Tertiary monzonite porphyry. Most of the copper mineralization is beneath a cover of Gila conglomerate.

Hydrothermal alteration in the vicinity is intense, and at least four types may be distinguished.

Type (1) is characterized at the surface by a light gray color and by alunite and kaolinite. This zone is known only from surface exposures, and most of the rock is monzonite porphyry. The original minerals and texture are largely destroyed, but shadows remain in thin section. Kaolinite and alunite are most abundant, but hydromuscovite, allophane, rutile, jarosite, hematite, and limonite are common; chlorite, potash clay, dickite, and halloysite were recognized.

Type (2) occurs in a zone nearly surrounding Type 1 and is characterized by high pyrite at depth and hematite where oxidized. Alteration is intense, but original texture is preserved. The characteristic minerals in unweathered rock are pyrite and hydromuscovite with lesser sericite, chlorite, leucoxene, rutile, allophane, kaolinite, hydrobiotite, and some montmorillonite and dickite in weathered specimens.

Type (3) occurs in a tabular zone along the south side of (2) which dips steeply southward. The characteristic minerals below the zone of weathering are sericite, pyrite, and chalcopyrite. Common are chlorite, rutile, quartz, hydromuscovite, kaolinite, hydrobiotite, allophane, potash clay, and more rarely alunite and adularia.

Type (4) is a less altered zone, but the alteration is mineralogically complex. The rock is dark gray owing to much finely disseminated biotite and hydrobiotite in the groundmass. Biotite altered to hydrobiotite, nontronite, chlorite, sericite, rutile, leucoxene, epidote, and calcite. Plagioclase shows partial alteration to sericite, hydromuscovite, potash clay, beidellite, and chlorite. Small amounts of pyrite and chalcopyrite are uniformly present. On the north this alteration is characterized by abundant epidote and zoisite.

PENNSYLVANIAN AMMONOIDS FROM THE STRAWN GROUP IN TEXAS

GAYLE SCOTT AND F. B. PLUMMER

This paper describes and illustrates new and little-known species of ammonoids of Desmoines age in Texas. In all, 16 species referred to 11 genera are described and illustrated. Of these 7 are new. Previously only 3 ammonoid species have been known from beds of Desmoines age in Texas. The addition of 7 new species and 6 already recorded from other States facilitates correlation of strata in Llano River valley in Kimble County with beds in Brazos River valley near Millsap in north Texas and with beds in southeastern Oklahoma. The new ammonoid species are, therefore, of interest from the standpoint both of stratigraphy and of phylogeny.

AGE OF THE AMSDEN FORMATION

HAROLD W. SCOTT

The discovery of the primitive fusulinid genus *Millerella* in the Amsden formation furnishes direct paleontologic evidence pertaining to the age of this formation. *Millerella* occurs in large numbers in one locality. They are associated with *Endothyra bowmani*, *Rhombopora nitidula*, *Amphissites* sp., *Bardia* sp., and *Cytherella* sp. They have been identified as *M. marbelensis* Thompson and *M. advena* Thompson. The fauna is interpreted to be Morrowan in age and is compared with unit 6 of the Wells formation in the Dry Lake section of Utah, the Kearney formation of Kansas, and the Brentwood of Arkansas.

The *Millerella* zone is in about the middle of the formation. Physical and paleontological evidence point to a Pennsylvanian age for the Amsden.

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PENNSYLVANIAN STRATIGRAPHY IN MONTANA AND NORTHERN WYOMING

HAROLD W. SCOTT

Pennsylvanian sediments of southern Montana and northern Wyoming consist of the Tensleep and Amsden formations. Deposition took place on the foreland area bounded on the west by the Cordilleran geosyncline and on the northeast by a low land mass.

Shore lines of the Amsden and Tensleep seas did not perfectly coincide. The lower Amsden represents sediments deposited in a transgressing sea. The initial transgression is characterized by basal sandstones and red shales, whereas the upper Amsden is characterized by dolomitic limestones. This sea is considered to be mostly Morrowan in age.

Three fusulinid zones are recognized; a lower *Millerella* zone limited to the Amsden, a middle *Fusulinella* zone, and an upper *Wedekindellina* zone, the latter two known only from the Tensleep.

After Tensleep deposition (Des Moines time) Pennsylvanian shore lines shifted continuously south and west, resulting in offlap. No beds younger than Des Moines are recognized in northern Wyoming and southern Montana. However, upper Pennsylvanian is recognized in the geosynclinal facies farther west on the basis of *Triticites*.

INTRODUCTORY STATEMENT REGARDING POLLEN ANALYSIS

PAUL B. SEARS

The outer coat of the spores of many vascular plants is resistant to decay. Such coats also generally exhibit characteristic patterns which, together with size and shape, are of great assistance in identifying the plants that produced them. Generic identification is most feasible, and specific differences may be obscure.

Many types of spores, including the pollen grains of a number of genera of seed plants, are produced in great quantities and disseminated by wind. Under appropriate conditions of sedimentation, and notably in bog silts and peats, they are well preserved and can be subsequently prepared for microscopic study.

Subjected to statistical examination—an operation known as pollen analysis—these spores shed light on the trend of vegetational history during the accumulation of particular sediments. Inferences regarding the climatic history of a region may be made by integration of such information.

The method of pollen analysis has been most extensively applied to post-Pleistocene sediments. It has also proved of value in study of interglacial deposits, in the correlation of archeological materials, faunal remnants, and the relative "dating" of geomorphological events. Somewhat similar methods are now being applied to the study of coal. Thus methods originally developed for study of recent changes in vegetation and climate now have more diversified significance.

FOSSIL BISON AND ASSOCIATED ARTIFACTS FROM TEXAS

E. H. SELLARDS

A fossil bison quarry, containing artifacts, on the High Plains of northwest Texas, discovered in 1944, was excavated in 1945. The bone bed, ranging from a few inches to 1½ feet thick is found at the base of valley fill, in a former stream channel. At the top of the bone bed the bones are more or less broken, while at lower levels they are usually complete and often in articulation. Whole skeletons are preserved but are difficult or impossible to separate entirely from associated skeletons. The accumulation of bison skeletons may have resulted from a bison stampede. Excavation of 62 running feet (500 square feet) of the bone bed yielded parts or all of skeletons of 50 or more bison, together with 27 artifacts. The artifacts include 19 projectile points (9 broken), 1 end scraper, 5 side scrapers or knives, and 2 flake scrapers. The projectile points are of the general Folsom-Yuma complex but are distinctive in character and are here designated the Plainview projectile. Measurements (not yet completed) have shown that the bison of this quarry is notably larger than the largest individuals of the modern species. The only other vertebrate found in the bone bed is a large wolf.

Fresh-water invertebrates are present. From near-by localities in the valley fill have been obtained *Parelephas columbi*, *Equus* sp., and an end scraper. Participating in this investigation, additional to the writer, are Glen Evans, Grayson Meade, Richmond Bronaugh, and Alex Krieger.

NOTE ON THE GEOLOGY OF AGATTU, AN ALEUTIAN ISLAND

ROBERT P. SHARP

Agattu lies near the western end of the Aleutian Chain. It is unique among the volcanic Aleutian Islands in being composed 80 to 90 per cent of well-bedded sedimentary rocks. At least 2000 feet of strata is exposed. The strata consist chiefly of amorphous silica and fine detritus derived from a volcanic terrain. The beds are gently tilted, faulted, and possibly folded. No fossils were found. The deposits may be as old as Cretaceous but are more probably Tertiary. Igneous rocks are sparsely represented by small intrusive bodies of porphyry, diabase, and trap.

The Agattu beds suggest that sedimentary rocks may be an important constituent of the western Aleutian-Komandorskie ridge and that this ridge may be in part of tectonic origin.

Agattu has been heavily glaciated. Ice almost entirely covered the island during the late Wisconsin and may have remained in places until the beginning of the post-Wisconsin optimum, 7500 to 8000 years ago. There are no glaciers on the island at present.

SUBMARINE PHOTOGRAPHY OFF THE CALIFORNIA COAST*

F. P. SHEPARD AND K. O. EMERY

Using the encased camera developed by Maurice Ewing several hundred photographs have been taken of the sea bottom off the coasts of southern California and Lower California. A sufficient number of photographs of various types of bottom were obtained to indicate the geological potentialities of the method. The photographs confirm evidence from dredging and other types of sampling that the banks off portions of the California coast are predominantly rocky with ledge rock and large boulders covering most of the surfaces. In some portions of the banks ripple-marked sand was found at depths as great as 70 fathoms. Giant ripples, about 6 feet across, were found on relatively flat bottom between rocky hills. On the other hand, large flat areas of sand free from ripples were found on the continental shelf in depths of 15 to 25 fathoms. Mud or sandy mud bottom was seen to have a considerable number of pock marks evidently due to organisms. A wall of one submarine canyon photographed has outcropping ledges of rock. The bearing of such a finding on the submarine canyon hypotheses is obvious.

This photographic method holds great promise for future studies of sedimentation and the ecology of benthonic organisms.

ORDOVICIAN TRENTON GROUP IN THE LOWER ST. LAWRENCE VALLEY

G. WINSTON SINCLAIR

Lower and Middle Trenton horizons can be traced from the Montreal area to and beyond Quebec City and maintain their faunal identity although varying in thickness and lithology. Northeast of Montreal the Tetreauville and Terrebonne limestones are replaced by shales, and their faunal characteristics are lost in the change of facies.

PRE-TRENTON ORDOVICIAN SECTIONS IN QUEBEC

G. WINSTON SINCLAIR

Examination of reported occurrences of Trenton strata as lowest Paleozoic sediments along the north shore of the St. Lawrence indicates that such outcrops reflect very local conditions. In each

* This work represents one of the results of research carried out by the University of California Division of War Research under contracts with the Office of Scientific Research and Development National Defense Research Committee Section 6.1, and with the Bureau of Ships, Navy Department.

case pre-Trenton beds were found exposed near by. Sections are given along three streams below Quebec City in which Black River and Chazy (?) beds are present.

GIANT GLACIAL GROOVES IN NORTHWEST CANADA

H. T. U. SMITH

In the Mackenzie Valley area west of Great Bear Lake, many ridges and mountain slopes are furrowed by glacial grooves on a scale far larger than previously recorded. Individual grooves range up to about 100 feet in depth and more than a mile in length. The grooves are essentially straight and parallel and occur closely spaced in zones reflecting the influence both of topographic exposure and of differential erodibility of the bedrock. The trend of grooves in the different zones is indifferent to structure and drainage and falls into a systematic pattern recording the advance of a continental ice sheet northwest along the Mackenzie Valley.

PERIGLACIAL ROCK STREAMS IN THE BLUE RIDGE AREA

H. T. U. SMITH AND ALTHEA PAGE SMITH

Bare, streamlike accumulations of boulders along valley bottoms occur at widely separated localities along the Blue Ridge from southern Pennsylvania to West Virginia. The boulders are loosely packed, unsorted, heterogeneous in size and shape, and range up to 12 feet in length. The sound of running water beneath the surface is audible. The accumulations are up to 1800 feet in length and 100 feet in width. Surface gradient is generally 3°–5°. The boulders are of quartzite derived from neighboring slopes and ridges. They are now lichen-covered, are undergoing disintegration in place, and show no evidence of appreciable present-day movement. The rock streams appear to be "fossil" forms and are best explained as a product of solifluction under periglacial conditions in Pleistocene time, with subsequent removal of interstitial material by running water. This explanation applies also to the boulder-choked valleys and subdued, overgrown talus slopes which are more widespread in the area.

STRATIGRAPHY AND STRUCTURE IN THE YAKATAGA AREA, ALASKA

E. M. SPIEKER, M. S. WALTON, JR., AND C. E. KIRSCHNER

The Yakataga area comprises part of the Alaskan Coast Ranges southwest of Mt. St. Elias—rugged, glacier-ridden, largely virgin terrane. The rocks are all sedimentary, intensely deformed, the youngest late Oligocene and the oldest probably early Tertiary in age. Four major stratigraphic units are recognized: two sandstone sequences, of total thickness 7500 to 10,000 feet, not named for lack of definitive information, overlain by the Poule Creek and Yakataga formations, late Oligocene in age, total thickness 10,000 to 12,000 feet. This is probably the thickest late Oligocene known in the world. The Yakataga formation contains unusual sedimentary types—cobble-bearing mudstones deposited in offshore marine waters, the crystalline cobbles and boulders dropped by melting icebergs; and varved siltstone-claystone units, of extraordinary interest because they were almost certainly deposited in marine waters. Late Oligocene conditions were similar to those of today. Locally the Yakataga formation exhibits astonishing lateral irregularity. Structurally the area is divisible into two folded belts separated by a major overthrust. Sharply pinched anticlines are separated by broad synclines; the structure is closely similar to that of the Jura Mountains and is probably of similar origin. Faults of all kinds abound. The age of the folding is probably late Tertiary, possibly late Pliocene. The land forms are very young and are undergoing rapid reduction.

MODERN ASPECTS OF GEOCHEMISTRY AND THEIR APPLICATION TO THE ECONOMIC GEOLOGY*

TAISIA STADNICHENKO

Previous to the development of atomic physics and the knowledge of the laws of crystal chemistry, geochemistry depended mostly on descriptive mineralogy and the data derived from the chemical

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analyses of the rocks and minerals collected in the different parts of the lithosphere, hydrosphere, and atmosphere. The recognition of the reality of the concept of the atom elements, systematic studies of their structures, and the laws of crystal chemistry gave a new impetus to the examination of the geochemical processes. While the frequency of occurrence of an element in the Cosmos depends on the structure of its atomic nucleus, the distribution, migration, accumulation, and dispersion of the chemical elements and their compounds are determined by the electrons of the outer shells. The behavior of the atom-element in the crystal lattice is governed by the laws of geometric equilibrium and a crystal represents a complex electromagnetic field which is determined by the energy of the system.

The laws of atomic lattices explain such well-known associations as: Cu, Co, Ni, and especially Cu and Fe; Zn, Fe, Mn; constant presence of Au in Ag; also less familiar series of Cd and In; Pt group with Fe, Cu, As, and Mo; presence of Re in Pt ores and Mo compounds. The geochemical processes leading to the separation of Co from Ni and Fe is a complex function including such variables as: atomic weight, atomic number, co-ordination number, energy of the crystal lattices, and ionic radii.

In last 20 years, particularly in Russia, the application of the new principles to the study of geochemical processes helped to formulate the important rules of geochemical associations, to forecast the distribution and accumulation of the various elements, and to suggest better means in solution of prospecting, mining, and technological problems.

BEACH INTELLIGENCE

STAFF OF BEACH EROSION BOARD

The Beach Erosion Board operates as a unit of the Office of the Chief of Engineers, War Department. Its part in beach intelligence began in June 1942 with a report of the channel coast beaches of France from Cherbourg to Dunkirk, and by the end of that year a program of a continuing succession of Strategic Engineering Studies on foreign beaches was well underway. Later the Board's reports were written directly for a volume published by a joint army and navy intelligence group. Two main types of reports have evolved from the early beginnings: (1) a brief graphic form used for strategic planning; (2) a longer, completely detailed operational report. The final development is the type of operational report written by intelligence teams overseas, such teams as those made up of members of the Military Geology Unit of the Geological Survey with one or two members of each team co-operating with the Beach Erosion Board.

An example is given of the approach used in writing a short strategic planning report, and an evaluation is made of the methods used in correlating available data into a complete physical picture of a particular beach area.

CONSTRUCTION PROBLEMS: AIRFIELDS, ROADS, AND GENERAL CONSTRUCTION

STAFF OF THE MILITARY GEOLOGY UNIT

In World War II, vastly increased use of air power and motorized ground equipment necessitated a comparable increase in planning for airfields and roads. For this purpose, military geologic intelligence studies co-ordinated data on, and interpretations of, ground, terrain, and drainage conditions. The types of information that could be supplied were: selection of possibly suitable areas (or even of actual sites) for airfield and road construction; evaluation of soil and rock conditions in possible construction areas or sites, for estimating ease of construction; evaluation of special topographic and drainage problems; determination of sources of construction materials and evaluation of their general suitability. The success with which these various types of information could be supplied depended on the basic information available. Where geologic maps, soils maps, and aerial photographs were on hand, remarkably accurate selections of sites and determinations of ground conditions were possible.

The study of construction problems in military operations has emphasized the need for more basic data on the engineering properties of soils and rocks (1) to establish general ground conditions, and (2) to determine the particular uses for which different soils and rocks are most suitable.

CORAL-REEF SEDIMENT AT MOROTAI, N.E.I.

STAFF OF THE MILITARY GEOLOGY UNIT

Photo-reconnaissance of Morotai, N. E. I., led to selection of the terraced, reef-bordered, southwestern peninsula of the island for airfield construction. The western shore of the peninsula, protected from southeast monsoonal winds and with approaches over an apparently shelving, sand-covered coral reef, was chosen for combat landings. On D-day, the reef on this side was found to be unsuitable because the apparent sand cover was actually thick, unconsolidated sediment or sludge of very low bearing ratio. Hasty ground observations and study of the literature suggest that the sludge is formed under the following conditions: Calcium bicarbonate in streams draining the limestone-terrace area is precipitated, by bacterial action, as a fine calcareous flocculate in the coastal mangrove swamps north of the landing area. Slow-moving, southerly longshore currents drift this precipitate from the mangrove swamps onto the reef surface. Almost complete protection from wave action permits the accumulation of a thick sludge cover.

In later over-reef landing operations, recognition of similar unfavorable conditions was made possible by the knowledge gained at Moratoi.

INFLUENCE OF ROCK AND SOIL COMPOSITION ON PERFORMANCE OF METALLIC MINE DETECTORS

STAFF OF THE MILITARY GEOLOGY UNIT

In foreign combat areas Allied troops found that their metallic mine detector was not effective over certain rocks and soils. Accordingly, the Military Geology Unit was asked by the Chief of Engineers to co-operate with the Engineer Board, Fort Belvoir, in correlating detector performance with rock and soil types, so that performance in enemy-held terrain could be predicted.

Field studies of rocks and soils in the Washington, D. C., area were made by geologist-pedologist-engineer teams using the detector. In addition, soil samples from many parts of the world were tested with a detector modified for laboratory use. The samples showed a wide range in reactivity, depending upon their parent rocks and the mineralogic changes which took place during weathering.

Field and laboratory tests showed that the performance of the metallic mine detector is closely related to soil and rock type. Therefore, knowing these for any area, the performance of the instrument is predictable, and "performance maps" can be constructed in advance of military operations. It was shown that the detector could be expected to perform effectively in the most probable combat areas in Japan and China.

The laboratory instrument should be of value in geologic and mineralogic research. It is compact and light and can be used in the field to measure the magnetic susceptibilities of most minerals, rocks, and soils.

MILITARY GEOLOGY UNIT: PURPOSE, AIMS, RESULTS

STAFF OF THE MILITARY GEOLOGY UNIT

In 1942, acting under the Corps of Engineers, U. S. Army, the Military Geology Unit, U. S. Geological Survey, was organized to furnish reports to be used at the strategic level of military planning. Intended for the use of Engineer and other officers, reports on terrain, water supply, and construction problems were phrased in nontechnical language. Particular emphasis was placed on terrain diagrams, maps, and other graphic means of presentation. Favorable reception of early reports, at the planning level and in combat areas, led to an expansion of the staff, from an original 10, to 125 members. To date, the Unit has completed more than 150 folio reports (of from 25 to 200 pages each) on all major combat areas. In addition, starting in 1944, the Unit has sent members of the staff overseas to help with tactical planning and construction and reconstruction problems. Approximately 75 members have served overseas.

The experience of the Unit has demonstrated: (1) That practical applications of geology and soils science can play an important role in military planning and operations. This fact is fully appreciated by the Corps of Engineers, who are requesting continued, peacetime work by the Unit. (2) That there is great need for collecting additional basic geologic and soils data, not only in almost unknown Pacific areas, but in our own country as well.

TERRAIN APPRECIATION: MILITARY APPRAISAL OF TERRAIN

STAFF OF THE MILITARY GEOLOGY UNIT

Terrain Appreciation implies description and appraisal of terrain in terms of its effects on movement of military forces and, incidentally, on cover, concealment, and observation. The appraisal is essentially an interpretation of data on physiography, ground conditions (rock and soil), and also land use, communications, and climate. Although the problem is fundamentally geologic, the need for details on soils and vegetation requires that specialists in these fields collaborate with geologists. The studies originally emphasized movement on existing routes, treating cross-country movement only in general terms. As the demand arose for more detail on problems of movement off roads, the treatment was supplemented by "trafficability" maps, showing the probable effects of soil, slope, vegetation, and weather upon movement of military traffic, particularly armor. The accuracy of the interpretations depended upon the available data and on the time permitted for their study. Where the data were good, results were remarkably satisfactory. Where the information was scanty or lacking, the gap was filled by analogy with physiographically similar areas, and interpretations were correspondingly generalized. Often, material had to be sacrificed to save time.

Experience in this work has clearly justified the geologic approach to the problem and has strongly emphasized the value of collecting all possible data on geology, topography, and soils. The trafficability studies, moreover, revealed a need for data on military vehicular performance as related to definite terrain and soil conditions, and on the behavior of various types of soil under traffic in different weather conditions.

GEOLOGICAL RELATIONSHIPS OF PLEISTOCENE, ARTIFACT-BEARING, LITTORAL DEPOSITS OF NORTHERN GEORGIAN BAY

GEORGE M. STANLEY

Excavations by the University of Michigan Archaeology Museum from 1938 to 1940 discovered artifacts and camp sites buried beneath wave-deposited gravels in abandoned beaches north of Manitoulin Island, Georgian Bay. Two sites were in post-Nipissing beaches 28 feet above Lake Huron, with antiquity of 1200 to 1400 years; a third in beach deposits (post-Nipissing) at 56 feet, about 2000 years in age. Discovery in 1940 of a site abounding with quartzite artifacts (semilunar blades, choppers, one hand axe, etc.), many wave worn, in a near-by late Algonquin beach, 297 feet above Lake Huron, is estimated to date man back roughly 10,000 to 15,000 years thereabouts. Antiquity of post-Nipissing beaches in any locality is approximately proportional to height above lake level, but this does not apply to late Algonquin (pre-Nipissing) beaches which are more steeply tilted than Nipissing or later beaches and accordingly separated therefrom by a considerable hiatus and time interval. The late Algonquin beaches "run out" in their northeastward rise against former ice barriers a few miles north of Sault Ste. Marie, and the ice sheet was scarcely 100 miles distant from the 297-foot beach when glacial Lake Algonquin waves formed it and rolled the artifacts found therein. Studies on varved clays and silts of the "Soo" region are in progress with hope of obtaining better dating for the Algonquin and late Algonquin beaches and associated human vestiges.

NOMENCLATORIAL SYNOPSIS OF THE FAMILY OSTREIDAE

H. B. STENZEL

About 111 generic and subgeneric names have been proposed for the various supraspecific groups of the family Ostreidae. Many of these names are invalid or otherwise useless from a taxonomic point of view.

The common American east-coast oyster, *Ostrea virginica* Gmelin, a well-known animal easily available for study, has received the following four supraspecific names: *Gryphaea* Lamarck 1801, *Crassostrea* Sacco 1897, *Euostrea* Jaworski 1913, *Dioeciostrea* Orton 1928. The common European oyster, *Ostrea edulis* Linné, might go under eight different generic names. Obviously it is necessary to discard faulty names and to establish a set of nomenclatorially valid and taxonomically useful names. The present paper lists all supraspecific names proposed for the family Ostreidae, discusses

the nomenclatorial validity of each, and cites the genotype species and their manner of designation. References to original and subsequent descriptions, as well as the type locality and geologic horizon, are given for each genotype species. The purpose of the paper is to provide precise and reliable nomenclatorial tools for taxonomic and phylogenetic studies of the family.

STRATIGRAPHIC SIGNIFICANCE OF THE PATAGONIAN ODONTOGRYPHAEAS

H. B. STENZEL

An outstanding problem of Argentinian stratigraphy is the age of the Roca beds (or Salamanqueano). The Salamanqueano, as understood by Feruglio 1938, has been placed variously in the Cenomanian, Maestrichtian, Danian, Paleocene, or lower Eocene. Due to the meager fauna the correlation rests chiefly on *Odontogryphaea rostrigera* Ihering and *O. pyrotheriorum* Ihering. Both species have been compared with and placed next to the Lower Cretaceous Gryphaeas of the southwestern United States by paleontologists who have discussed them. Although these two oysters are convergent toward *Gryphaea* they are not closely related to *Gryphaea*. The genus *Odontogryphaea* is represented outside of Patagonia by *O. thirsae* (Gabb) and a new species of the Nanafalia formation of the Gulf Coast of North America and *O. heteroclita* (Defrance) of the Thanetian of France and western India. The acme of the genus is in the Paleocene to lowest Eocene, and its extinction takes place near the Paleocene-Eocene boundary. The two Patagonian species indicate a probable Thanetian or Ypresian age for the Salamanqueano, which is part of the Roca beds.

OYSTERS OF THE *ODONTOGRYPHAEA-FLEMINGOSTREA* STOCK

H. B. STENZEL

The two closely related genera *Odontogryphaea* Ihering 1903 and *Flemingostrea* Vredenburg 1916 have a peculiarly folded valve commissure and other distinctive characters that segregate them clearly from other ostreids. *Odontogryphaea* converges toward *Gryphaea* Lamarck 1801, with which it has often been confused, but the similarities are superficial and their relations distant. Although a primitive *Odontogryphaea* occurs in the Maestrichtian of India the acme of the genus is in the Paleocene, and it disappears near the Paleocene-lower Eocene boundary. Representatives of the genus are reported from India, France, Gulf Coast of North America, Mexico, and Patagonia. *Odontogryphaea* is probably a descendant of *Flemingostrea*, whose acme is in the Upper Cretaceous. *Flemingostrea* has species in the Atlantic and Gulf Coastal Plain of North America, Trans-Pecos Texas, Mexico, Peru, and Sind and Pundjab provinces of India. *Flemingostrea* is probably a descendant of *Amulostrea* Vialov 1936. Distinctive characters, world-wide distribution, and relatively narrow stratigraphic range make this stock significant in intercontinental correlations.

SIPHOGENERINOIDES CUSHMAN (FORAMINIFERA, BULIMINIDAE)*

BENTON STONE

Siphogenerina Schlumberger (1882, *in* Milne-Edwards) and *Siphogenerinoides* Cushman (1927) currently are diagnosed as triserial and biserial, respectively, in the initial stages of their microspheric generations. Thin sections and decorticated specimens show that both are triserial in that form. They are differentiated, however, by the circular aperture inclosing the siphon, in *Siphogenerina*, as opposed to the reniform aperture of *Siphogenerinoides* which does not inclose the siphonal orifice. Typical species of *Siphogenerinoides* are restricted to the Upper Cretaceous. Related forms in the lower Tertiary tentatively are placed in a new subgenus. Five new species are described from the Upper Cretaceous of Northwestern Peru.

* Presented by permission of the Chief Geologist, International Petroleum Company, Limited, Toronto, Canada.

REVISION OF THE FAMILIES AND GENERA OF THE DEVONIAN TETRACORALLA

ERWIN C. STUMM

The following families and subfamilies are recognized: Petraiaidae; Syringaxonidae; Metriophyllidae; Hadrophyllidae; Zaphrentidae; Aulacophyllidae; Acrophyllidae; Acanthophyllidae, Leptoinophyllidae with subfamilies Leptoinophyllinae, Mictophyllinae, Grypophyllinae, and Stringophyllinae; Disphyllidae with subfamilies Disphyllinae, Pachyphyllinae, and Eridophyllinae; Columnariidae with subfamilies Columnariinae, Spongophyllinae and Endophyllinae; Digonophyllidae with subfamilies Digonophyllinae and Zonophyllinae; Lithophyllidae with subfamilies Lithophyllinae and Arcophyllinae; Chonophyllidae; and Calceolidae.

Two new genera are proposed and a new family is based on one of them.

STRATIGRAPHY AND PALEONTOLOGY OF THE DETROIT RIVER LIMESTONE IN NORTH-CENTRAL OHIO

ERWIN C. STUMM AND FRED FOREMAN

The upper 62 feet of the Detroit River limestone is exposed in quarries near Bellevue and Castalia, Ohio, lying directly beneath the Columbus limestone. The upper 32 feet is composed of fine grained gray to buff dolomitic limestone with occasional thin lenses and bands of white or gray chert. A continuous layer of chert is present about 11 feet below the contact with the Columbus limestone. Fossils are very rare in the dolomite but are present and fairly well preserved in the chert bands. The following fossils are characteristic: Corals; *Zaphrentis cornicula*, *Heterophrentis* sp., *Disphyllum profundum*, *Favosites turbinatus*, *Ceratopora* sp. Brachiopods; *Stropheodonta parva*, *S. perplana*, *Chonetes mucronatus*, *Camarotoechia tethys*, *Pentamerella arata*, *Spirifer divaricatus*, *S. cf. varicosus*, *Elythia fimbriata*, *Prosserella lucasi*. Pelecypods; *Conocardium* cf. *trigonale*, *Pterinea bradti*. Gastropods; *Platyceras carinatum*, *P. dumosum*, *P. erectum*. Trilobites; *Proetus crassimarginatus*, *Phacops cristata*, *Dalmanites* sp.

This member is correlated with the Lucas limestone of northwestern Ohio.

The lower 30 feet is composed of dark gray to drab, fine to coarsely crystalline dolomitic limestone with much secondary calcite and containing 6 to 18 inch layers of mixed dolomite and quartz sand grains mainly in the lower part. The same grains make up to 50% of the content of these layers. The surface pitting, shape and roundness factor, and the heavy mineral distribution of the sand in these sandy layers is identical with those found in the Sylvania sandstone, and seems to represent an eastward interfingering of the Sylvania sandstone across the Cincinnati Arch. The fauna of this member is poorly preserved, but the following have been found in the upper layers: *Zaphrentis cf. cornicula*, *Favosites turbinatus*, *Prosserella modestoides*, *P. subtransversa*, *Conocardium* cf. *trigonale* and *Proetus crassimarginatus*. The upper part of this member is correlated with the Amherstberg member and the lower part seems to be an eastward equivalent of the Sylvania sandstone. The fauna indicates that the Detroit River formation is of middle Onondaga age.

SOME FOSSIL GASTROPODS FROM THE ALLEGHENY FORMATION OF EASTERN OHIO

MYRON T. STURGEON

Macroscopic gastropods have been collected from four of the five marine members of the Allegheny formation of eastern Ohio. In ascending order the members yielding gastropods are the Putnam Hill, Vanport, and Hamden limestones and the Washingtonville shale. The largest number of specimens and also of genera and species is from the Vanport and Hamden members, and a much smaller number is from the Putnam Hill limestone and the Washingtonville shale. Twenty-five possible species distributed in 17 genera are recognized from the present study.

UPPER JURASSIC OSTRACODA FROM THE SCHULER FORMATION OF THE NORTHERN GULF COASTAL PLAIN

FREDERICK M. SWAIN

The Schuler formation has been previously defined by the author as forming the upper part of the entirely subsurface Cotton Valley group in the region of the Northern Gulf Coastal Plains.

On the north, in southern Arkansas, the Schuler comprises upper pastel sediments and lower red beds that are mostly unfossiliferous but from which a single example of the nonmarine or brackish-water ostracode genus *Cypridea* Bosquet has been obtained. It is comparable to *C. wyomingensis* Jones, which, according to Peck, occurs in the Lower Cretaceous Draney formation in Idaho and Wyoming. The Schuler occurrence is not thought to provide basis for regional correlation, but it bears upon interpretation of the paleogeography of Schuler time.

To the south, in Northern Louisiana and Northeastern Texas, the Schuler formation passes into a facies of dominantly marine, shallow-water sediments that contain Foraminifera and Ostracoda as well as a number of megafossils that suggest an Upper Jurassic age, according to Imlay. Studies of the ostracode faunule now being carried on by the author, partly in collaboration with F. M. Swartz, have resulted in recognition of 15 new species distributed among 4 genera, 3 of which are new. Synopses of the new genera are presented, together with a discussion of problems relating to their classification. A zonal arrangement of the species appears to be likely, but delineation of the possible zones requires examination of many additional well records.

BURIED MISSISSIPPIAN SLUMP BLOCKS IN THE BASAL PENNSYLVANIAN OF ILLINOIS*

DAVID H. SWANN

Well logs indicate the presence in south-central Illinois of a pre-Pennsylvanian erosion surface on which a prominent feature is an escarpment capped by a limestone bed in the lower part of the Kinkaid formation (Mississippian). Topographic relief along this feature reaches 180 feet between wells 660 feet apart. In three small areas a short distance below this escarpment, wells penetrate sections of the Kinkaid and underlying Degonia formations which are displaced 30 to 120 feet below their normal stratigraphic position. The best-defined instance is interpreted as a slump block nearly 2000 feet long, several hundred feet wide, and 60 or 70 feet thick incorporated in the basal Pennsylvanian sediments. It is located at a depth of about 1800 feet on the southeastern edge of the Iola oil field, northwestern Clay County.

ZONAL OSTRACODA OF THE LOWER DEVONIAN IN NEW YORK AND PENNSYLVANIA

FRANK M. SWARTZ

Ostracoda are locally common in Lower Devonian, post-New Scotland siliceous limestones in southeastern New York, eastern and central Pennsylvania, and western Maryland. Thlipsuridae form a high percentage of the species and are valuable in recognition of six zones. No more than two zonal faunules have yet been discovered at any one locality; evolutionary as well as stratigraphic data establish their order of sequence. Of special value are the overlapping evolutionary series, *Thlipsurella octonariformis* → *T. multipunctata* → *T. secoclefta*, and *Thlipsura dawsi* → *T. confluens*. These are used in the following zonation:

Thlipsura confluens, with *Parenthelica parenthiformis*, Glenerie limestone, Catskill, New York; may belong below zone of

Thlipsura confluens, with *Thlipsurella secoclefta*, Glenerie near Kingston, New York, upper Shriver in central Pennsylvania.

Thlipsura confluens, with *Thlipsurella ellipsoclefta*, middle Shriver, central Pennsylvania.

Thlipsura confluens, with *Thlipsurella multipunctata* and *Parenthelica trisulcata*, Glenerie beds at Alsen, New York; middle Shriver near Cumberland, Maryland, and Keyser, West Virginia.

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Thlipsura dawsi, with *Thlipsurella multipunctata* and *T. lachrymosa*, upper Port Ewen, Kingston, New York; Monroe County, Pennsylvania; Mandata formation, Perry County, Pennsylvania. *Thlipsurella octonariformis*, Mandata beds, Fulton County, Pennsylvania; Highland County, Virginia.

MID-PALEOZOIC OSTRACODA IN EXPLORATORY WELL IN GEORGIA; MUSCLE SCARS IN LEPERDITIIDAE

FRANK M. SWARTZ

Flat-lying shale, below Cretaceous deposits in an exploratory well in southern Georgia, and variously classed as Triassic or Late Paleozoic, contains new Ostracoda rich in individuals though limited in species. *Diagonella* has sharp cardinal angles as in many mid-Paleozoic genera; lack of pouched dimorph suggests Drepanellidae not Kloedeninae. Uncertainty of overlap in a kloedenellid leaves uncertain its reference to *Kloedenella* versus *Jonesina*. A short-hinged form suggests species questionably classed in *Aparchites*. *Carnarvonopsis*, with venose lines radiating from adductor scar, is provisionally placed in Leperditiidae. "*Leperditia*" *chevronalis* shows scars of adductor and inner, subocular chevron mark, has nondenticulate hinge.

To investigate significance of *L. chevronalis*, *Leperditia* has been reviewed. Subocular chevron marks appear in Oehlert's figures of the genotype, *britannica*; Kolmodin's enlargement of *hisingeri*; Jones' drawings of *scalaris*; Kegel's illustrations of *Herrmannina* and *Briartina*. Photographs and camera-lucida drawings of *Leperditia scalaris*, *L. altiscalaris*, *Dihogmochilina straitcreekensis* show details of adductor and chevron scars, of scars dorsal to eye tubercle. *Scalaris* has denticulate hinge once thought to distinguish *Herrmannina;* this latter genus is distinguished from *Leperditia* by lack of post-dorsal swelling of left valve, and as now known is common in Silurian of North America, Silurian and Middle Devonian in Europe. Mid-Ordovician *fabulites* lacks chevron mark, has nondenticulate hinge, is type of new *Eoleperditia*.

Chevronalis of Georgia well has muscle scars of *Leperditia*, nondenticulate hinge of *Eoleperditia*. Exact correlation is not now evident, but mid-Paleozoic age is plausible, and the faunule should have value in future correlations.

ORIENTATION, MORPHOLOGY, AND CLASSIFICATION OF PALEOZOIC STRAIGHT-BACKED OSTRACODA

FRANK M. SWARTZ

The swing of the shell, extensively employed in orienting Paleozoic straight-backed Ostracoda, may be reversed in some groups as compared to others. If this be true, it doubtlessly reflects morphologic differences important in classification. To discuss shell features in terms of swing, the end toward which the swing is directed is termed the plenate end, because of its relatively full outline. Features toward this end are adplenate; toward the other, antiplenate.

Most significant in orientation of Paleozoic Ostracoda are (1) the swing itself, forewards in most modern Ostracoda with which comparisons are feasible; (2) dimorphic pouches which presumably housed young, somewhat as embryos are retained posteriorly in females of modern *Cytherella;* (3) position of adductor, commonly anterior to midlength in modern groups; (4) position of presumed eye tubercles in Leperditiidae.

In Kloedenellidae, direction of swing combines with antiplenate position of dimorphic swellings to indicate that plenate end is anterior. In Beyrichiidae and Zygobolbidae, the ventro-adplenate pouches suggest that antiplenate end is forward, but questions are raised by adductor locations. In Leperditiidae, adductor and eye tubercle are decidedly antiplenate, and antiplenate end is plausibly anterior. Where known in Aparchitidae, the adductor is adplenate, and plenate end may belong at front.

Anterior fullness in modern Ostracoda evidently results from strength of head and weakness of posterior parts. In ostracode-like, Cambrian *Hymenocaris*, head parts are small, abdomen large, and posterior end plenate. If in Beyrichiidae the dimorphic pouches are posterior, plenation of the

then posterior end indicates morphologic divergence from Kloedenellidae, which with their antiplenate pouches are placed in new Kloedenellacea. Posterior plenation of Leperditiidae suggests morphologic characters reminiscent of *Hymenocaris*; divergence of the superficially similar Aparchitidae is emphasized by proposed new name Aparchitacea. Subfamilies of the Bevrichiacea are considered.

REVISION OF SYNPHORIINAE, WITH NEW TRILOBITES FROM THE LOWER DEVONIAN OF PENNSYLVANIA

FRANK M. SWARTZ

A study beginning with 11 new trilobites from the Lower Devonian of Pennsylvania has led to investigation and reillustration of 18 additional species, the total group being distributed through 15 genera and 5 families. Three new genera are proposed; new photographs of specimens of *Dalmanites vulgaris* from England and of *Odontochile hausmanni* from Bohemia aid closer definition of the new genera; modifications are also made in *Synphoria*, *Dalmanitoides*, and *Synphoroides*. It is suggested that the primary distinction between the Dalmanitinae and Synphoriinae is the peculiar suborbicular ridge of the latter group. The incidence of this feature needs further investigation, but with the available information it appears that the Dalmanitidae of the Lower Devonian of North America are Synphoriinae in the sense that they possess the ridge, whereas the Dalmanitidae of the Silurian of North America and Europe and of the Lower Devonian of Europe are seemingly Dalmanitinae on this basis.

NEW STRUCTURES IN EARLY DEVONIAN CONULARIDAE

FRANK M. SWARTZ AND EUGENE S. RICHARDSON, JR.

Seventeen specimens of Conularidae from the Lower Devonian Shriver chert and the Middle Devonian Onondaga shale of Pennsylvania represent six new species and occur mostly in the form of molds displaying the internal and external structures of the shells to exceptional advantage. Some of the examples correspond to thin-walled shells of the typical *Conularia* type, and one of these is broken at a septum near the apical end. Others have shell walls far thicker than any previously reported in this family. These thick-walled individuals lack the septa; the apex is punctured by a short siphuncle closed at its inner end. Probably the siphuncle sheathed an organ of attachment something like the apical cups discovered by Ruedemann in young of *Conularia gracilis* Hall, though there was no apical perforation in those shells. The excessive thickness of the shell wall may prove to be a gerontic feature, though some evidence is to the contrary.

PETROGRAPHIC COMPARISON OF PLIOCENE AND PLEISTOCENE VOLCANIC ASH FROM WESTERN KANSAS

ADA SWINEFORD AND JOHN C. FRYE

Lenticular, discontinuous deposits of volcanic ash occur in western Kansas in at least two stratigraphic positions within the Pliocene Ogallala formation and in one or more within the Pleistocene strata. The ash, which is extensively mined, attains a known maximum thickness of more than 20 feet. In an attempt to determine the feasibility of stratigraphic correlation by minor petrographic differences in the volcanic ash, a study was made of 30 samples from 8 Pliocene localities and 24 samples from 10 Pleistocene localities. Sieve analyses showed no consistent difference among the several samples even though a few zones of Pliocene ash were coarser than any sample of Pleistocene age. A color comparison of the fraction finer than 62 microns showed a consistent difference. Color differences are less pronounced in the coarser grades. A refractive index of about 1.501 is common to all Kansas samples studied except those from one Pliocene locality (R. I. ca. 1.506). The most prominent difference between the ash of the two ages is the presence of numerous elongated fluid inclusions in many shards in the Pleistocene samples. These are rare in the Pliocene ash, most of the particles of which are either clear or clouded with mineral and small equidimensional fluid inclusions. Chemical analyses of 27 samples show the Pliocene ash to be generally higher in iron. A sample of Pliocene ash from Hemphill County, Texas, showed most characteristics typical of Kansas Pliocene samples but had a refractive index of about 1.496.

PRELIMINARY CHEMICAL CORRELATION OF CHROMITE WITH THE CONTAINING ROCKS*

T. P. THAYER

Chromite investigations of the Geological Survey since 1939 indicate that economic deposits of chromite rich in normative spinel ($(Mg/Fe)Al_2O_4$) occur in peridotites closely associated with gabbro; high-chrome chromites occur in feldspar-free peridotites; and chromites rich in both normative chromite ($(Mg/Fe)Cr_2O_4$) and magnetite (Fe_3O_4) are found in the pyroxene-rich stratiform complexes. Reaction of high-alumina chromite with diopsidic gabbro to form anorthite, olivine, and enstatite is described, and some probable equilibria between chromite and silicate minerals are discussed.

A plot of 60 complete analyses on a triangular prism of composition shows that chromites from different geologic provinces in the Western Hemisphere vary consistently and fall in overlapping, but distinct, fields. The chromites of the Caribbean Province, which occur in dunite and troctolite, have the general formula $Cr_{25-80}\ Al_{15-75}\ Mt_{1-5}\ (Mg_{65-75})$ and average about $Cr_{50}Al_{47}(Mg_{70})$. The chromites of the Pacific Coast, which occur in dunite and saxonite, average about $Cr_{70}Al_{24}(Mg_{60})$ in the range $Cr_{60-77}Al_{18-35}\ Mt_{3-15}(Mg_{45-75})$. The chromites of the Stillwater complex, like the stratiform Bushveld ores, occur in bronzite-rich rocks and are richer in iron; they average about $Cr_{60}Al_{32}$ (Mg_{52}) and cover the range $Cr_{52-69}Al_{24-39}Mt_{5-10}(Mg_{45-61})$.

MECHANICAL EFFECTS OF STREAM TRANSPORTATION ON MINERAL GRAINS OF SAND SIZE

GEO. A. THIEL

The manner and condition under which sand grains become rounded have been discussed by numerous investigators. Many opinions have been expressed, but few facts have been contributed. The published quantitative data are limited mainly to studies of coarse sediments such as cobbles, boulders, and small artificial blocks of concrete.

In this study data were obtained by subjecting mineral grains of the 1 mm. and ½ mm. grades to abrasion in running water. Several grams of crushed and screened mineral grains were placed in 2 or 3 liters of water which contained quartz grains equal in size and total weight to the mineral to be tested. The water with the minerals was allowed to flow in a rubber tube mounted on a rotating drum. The speed of rotation was adjusted so that the water flowed at the rate of 2 miles per hour.

Preliminary experiments indicated that 60 to 100 days of continuous flow were required to produce significant changes on most of the minerals. Their relative resistance was determined by measuring losses in weight and changes in the degree of sphericity of the mineral grains. On the basis of the loss in weight of the 1 mm. grade, the minerals tested showed the following order from the least to the greatest resistance: barite, siderite, fluorite, goethite, enstatite, kyanite, bronzite, hematite, augite, apatite, spodumene, hypersthene, diallage, rutile, hornblende, zircon, epidote, garnet, titanite, staurolite, microcline, tourmaline, quartz.

Changes in the degree of sphericity of the mineral grains were determined by using Wadell's formula.

EVOLUTIONARY TRENDS OF THE FUSULINIDS AND THEIR APPLICATION TO CORRELATION AND ZONATION OF PENNYSLVANIAN ROCKS

M. L. THOMPSON

Fusulinid foraminifers are abundant and widely distributed throughout marine Pennsylvanian and Permian rocks in America and have proved to be among the best index fossils for correlation and zonation of Pennsylvanian and Permian rocks. The classification of fusulinids is based largely on internal features of the shell, features that probably were little affected by local environmental conditions.

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Several dominant trends in the evolution of the fusulinids were developed in different branches of the family independently and at different times during the Pennsylvanian and Permian. During lower Pennsylvanian time some of these trends reached a maximum degree of development, and their recognition furnishes bases for correlation of rocks in widely separated localities. These evolutionary trends are discussed and their relationship to the current classifications of Pennsylvanian rocks in America is pointed out.

MORROWAN AND DERRYAN FUSULINIDS OF NEW MEXICO AND EXTREME WESTERN TEXAS

M. L. THOMPSON

Lower Pennsylvanian rocks of New Mexico and extreme western Texas contain abundant faunas of fusulinid foraminifers and are referred to the Morrowan and Derryan series. Rocks of Morrowan age contain faunas of *Millerella* and are referred to the zone of *Millerella*. Rocks of Derryan age contain *Millerella*, *Nankinella*?, *Eoschubertella*, *Pseudostaffella*, *Profusulinella*, and *Fusulinella*. Forms of *Profusulinella* predominate in the lower Derryan, and forms of *Fusulinella* predominate in the upper Derryan. Accordingly, lower Derryan rocks are referred to the zone of *Profusulinella*, and upper Derryan rocks are referred to the zone of *Fusulinella*. In this paper 5 species of *Millerella*, 1 species of *Nankinella*?, 2 species of *Eoschubertella*, 1 species of *Pseudostaffella*, 6 species of *Profusulinella*, and 10 species of *Fusulinella* are described and illustrated. These faunas are compared with other pre-Desmoinesian fusulinid faunas of America.

VASQUEZ OVERTHRUST, MIDDLE PARK, COLORADO

OGDEN TWETO

The Vasquez Mountains extend northwesterly into southeastern Middle Park, Colorado, from the Front Range west of Berthoud Pass to the Colorado River at Hot Sulphur Springs. The northern part is in a northwesterly zone that is a major unit of a northerly belt of en echelon zones of overthrusting along the eastern margin of Middle and North parks.

The Vasquez Mountains consist largely of gneisses and schist (pre-Cambrian Idaho Springs formation), but sedimentary rocks occur in the northern part. These include the Jurassic Morrison shales and sandstone (50–150 feet), Upper Cretaceous Dakota sandstone (400 feet), Benton shale and sandstone (450 feet), Niobrara limestone and calcareous shale (450 feet), and Pierre shale (2000 feet). The late Cretaceous (?) Middle Park consists of andesitic breccia, agglomerate, and flows (400–600 feet), conglomerate that grades from andesitic at base to a mixture of andesitic and pre-Cambrian detritus at the top (300–500 feet), and grit (1500 feet). Undeformed Tertiary lake beds and volcanics cover the older rocks in the lower parts of the basin.

The Middle Park formation is involved in the folding and thrusting that climaxed Laramide orogeny, and the angular unconformity below it represents earlier orogeny.

The Vasquez overthrust, the principal structural feature of southeastern Middle Park, has been traced from Byers Peak northwesterly for 18 miles to Hot Sulphur Springs. Northwest of Hot Sulphur Springs it may be continuous with a zone of strong faulting on the west edge of North Park. Continuation southward within the pre-Cambrian west of Byers Peak is suggested by local structural discordance in the pre-Cambrian rock, scattered patches of retrogressively metamorphosed gneiss, and by schist on the western side of the mountains, in contrast to predominating gneisses on the east side.

South of Crooked Creek it is a single strongly warped and fractured fault surface that strikes generally north and dips 10° E. Its minimum displacement of 4 miles brings strongly faulted pre-Cambrian gneisses over thin sedimentary sections in three open northeasterly synclines, and over the pre-Cambrian cores of the intervening anticlines.

North of Crooked Creek, where the Pierre and Middle Park formations thicken the section, strong folding accompanied thrusting, and the overthrust comprises three easterly dipping fault surfaces ¼ to 2 miles apart. Two and possibly all three faults reunite a few miles southwest of Hot Sulphur Springs. The western fault is the oldest and steepest, and the eastern is the youngest.

ARTIFICIAL RECHARGE OF ARTESIAN LIMESTONE AT ORLANDO, FLORIDA*

A. G. UNKLESBAY AND H. H. COOPER, JR.

The principal aquifer in the Orlando area consists of 900 feet or more of permeable artesian limestone of upper and middle Eocene age. As in most other parts of the Florida peninsula, this limestone is overlain by the Hawthorn formation of Miocene age which contains relatively impervious beds. The Hawthorn at Orlando is 45 to 100 feet thick and prevents or retards natural recharge to the limestone formations except where it is penetrated by what appear to be old sinkholes that are now filled with previous material.

Owing to the lack of adequate surface drainage, more than 175 wells have been drilled into the limestone in the Orlando area to drain streets, control lake levels, and dispose of sewage and other waste liquids. Generally the piezometric surface of the water in the principal aquifer is far enough below the land surface to allow drainage by gravity. As the limestones are cavernous, most of the wells have large capacities for draining water and seldom become clogged although a considerable amount of rubbish is carried into them.

The piezometric surface of the artesian water is conspicuously higher where drainage wells are concentrated, evidently because of recharge through the wells. However, the effect of the artificial recharge cannot be clearly differentiated from that of natural recharge. A deep-well current meter was used successfully to determine the horizons at which the polluted surface waters enter the limestone.

The investigation was made in co-operation with the Florida Geological Survey and the Corps of Engineers of the U. S. Army.

BLACKHAND SANDSTONE IN OHIO

KARL VER STEEG

The Blackhand sandstone and conglomerate member of the Cuyahoga formation has been one of the perplexing problems of the Waverly series. This conglomeratic sandstone, correlated with the Big Injun sandstone of southeastern Ohio, forms the scenic cliffs and deep gorges in the Hocking County region, at Old Man's Cave, the Rock House, Ash Cave, Cantwells Cliff, Conkles Hollow, and Cedar Falls.

The conglomeratic facies of this sandstone occurs in elongate masses extending from Vinton into Richland and Ashland counties, a distance of more than 100 miles, and reaching a thickness of 400 feet. These conglomeratic masses trend slightly west of north. The character of the sediments and the dip of the bedding planes suggest deposition in shallow water in rather strong currents with scouring action. Apparently the currents came from the south because the true bedding planes dip 5°–15° N., NE., E., and NW.

The pebbles are milky-white quartz ranging from less than a quarter of an inch to more than 2 inches in length. The source of this quartz has not been determined.

When traced horizontally from the conglomeratic masses, the Blackhand member becomes thinner, contains more shale, the sandstones are finer in grain and do not exhibit the strong cross-bedding and evidence of scouring action. This change in facies is accounted for by the explanation that it is part of a delta. However, it could be a beach, bar, or spit.

MAGNESIUM MINERALIZATION IN THE CURRANT CREEK DISTRICT, NEVADA

CHARLES J. VITALIANO

The Currant Creek district is in White Pine and Nye counties, Nevada, 35 miles southwest of Ely, Nevada.

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The host rock is a late Miocene or early Pliocene bedded calcareous tuff, overlain by quartz latite and underlain in the western part of the area by basaltic andesite and dacitic rock and in the eastern part of the area by dacite. The tuff varies in thickness but averages 300 feet. Unaltered tuff may contain as much as 80 per cent carbonate. All beds dip gently eastward from the summit of the Horse Range, but they are broken by a number of northeasterly trending major faults and several minor faults of variable trend.

Magnesite replaces the calcareous tuffs and occurs as nodules, as veins or lenses, and as disseminated grains in masses of unaltered tuff. The associated minerals are dolomite, an unnamed magnesium silicate, possibly a member of the serpentine group, calcite, and silica in the form of chalcedony, opal, and quartz. The hard, dense, white nodules are distributed in zones, commonly 100 feet or more in length. The lenses or veins may reach a length of 100 feet and a width of 12 feet but are generally much smaller.

The silica minerals are late and transgress the others. Magnesite is earlier than the silica minerals. Its relation to the other carbonates is not always clear, but it is probably later than most of the dolomite.

The alteration is believed to have been due to ascending hot spring waters, rich in magnesia, that formed the magnesium silicate and dolomite, which were replaced in turn by magnesite. Later solutions deposited various forms of silica which cut or replaced earlier minerals.

BURIED PRE-CAMBRIAN HILLS IN NORTHEASTERN BARTON COUNTY, CENTRAL KANSAS

ROBERT F. WALTERS

Six buried pre-Cambrian hills are defined by 952 oil exploration tests drilled within the 160 square miles mapped. These flat-topped hills were quartzite monadnocks on a Cambrian peneplane eroded across pre-Cambrian quartzite, schist, granite, syenite, granite gneiss, and pegmatite. During the deposition of the lower 220 feet of Cambro-Ordovician Arbuckle beds these monadnocks were islands. On their slopes sediments were deposited with 2- to 5-degree initial dips. They were buried under 340 feet of upper Cambro-Ordovician dolomites, under 40 feet of Ordovician Simpson shale, and probably also under 650 feet of younger pre-Pennsylvanian strata. Erosion culminating in an early Pennsylvanian peneplane exhumed the hills. Slight uplift followed. The paleo-outcrop belt of the truncated Cambro-Ordovician dolomites became a youthful karst plain pitted by sinkholes. Solution valleys to 1½ miles in width fringed each resurrected hill at the dolomite-quartzite contact. These solution depressions are partially filled with untransported leached residuum (chert, clay, sand) and with transported residuum-derived material deposited both as nonmarine and marine Pennsylvanian conglomerate. In late Des Moines time the pre-Cambrian hills became diminishing islands in a transgressing sea. Limestones of the Missouri series were deposited on their summits. They are now buried under 3300 feet of Pennsylvanian, Permian, and Cretaceous rocks.

The data obtained in this 4-year sample study were summarized graphically by plotting the height of the hills above the average ground surface, or their depth of burial, as ordinates and geologic time as abscissas. The resulting curve summarizes quantitatively the vertical movements experienced by the quartzite hills from late pre-Cambrian time to the present.

UPPER MISSISSIPPIAN AND PENNSYLVANIAN STRATIGRAPHY OF PART OF WESTERN WYOMING*

H. R. WANLESS, RUTH BACHRACH, EDWARD ZELLER, DOROTHY JOHNSON

The later Mississippian and Pennsylvanian rocks of Teton, Lincoln, and Sublette counties, Wyoming, are referred to the Amsden and Tensleep formations of central Wyoming and the Brazer and Wells formations of Utah and Idaho. These rocks were studied at several localities in the Gros Ventre, Teton, Hoback, Wyoming, and Snake River ranges and in Jackson Hole. In the Teton and Gros Ventre ranges and Jackson Hole the aggregate thickness of these rocks is 500–1000 feet, and they belong to a foreland facies, but in the Hoback, Wyoming, and Snake River ranges their

* Report on studies carried out at the University of Michigan Rocky Mountain field station, Camp Davis, Jackson, Wyoming.

combined thickness is 1000–2200 feet, and they are of geosynclinal facies. Rocks referred to the Brazer are mostly dense lithographic limestone varying from light gray and pink to very dark gray and nearly devoid of fossils. They include two or three widespread zones of sedimentary breccia. The Amsden includes, from the base up, red shales and associated limestone, a widespread sandstone, the Dorwin, and additional red shales and limestones, and a thin iron ore. In the north-central Hoback Range there are locally 30 or more beds of gypsum in the Amsden, and perhaps also in the upper Brazer. The Tensleep formation consists principally of quartzitic sandstone alternating with numerous widespread beds of dense somewhat cherty limestone. Although both the Amsden and Tensleep are rather unfossiliferous in this area, there is some evidence that the Amsden includes strata of Morrow or Lampasas age and that the Tensleep includes strata of Des Moines and Missouri age belonging to both the *Fusulina* and *Triticites* zones.

ANADARKO BASIN TECTONICS*

ROBERT W. WHEELER

The war-accelerated search for oil prospects in western Oklahoma permits new ideas regarding the age and mechanics of Anadarko Basin structural movements. At variance with the generally accepted concept of a deep asymmetric trough bordering an upfaulted Arbuckle-Wichita Mountain front formed during late Mississippian time is evidence that this structural relief (amounting to about 20,000 feet in Caddo County) was achieved during two main periods of movement, an early period of folding in pre-Cherokee = Deese time, and a period of severe faulting in late Pennsylvanian (pre-Pontotoc) time by the development of northwest-trending fault blocks and folds en echelon to the west-northwest Arbuckle = Wichita-Amarillo granite arch.

These en echelon features plunge northwestward and southeastward away from the granite axis and are characterized by structural transition from thrust faulting and overturned folds through normal faulting to simple elongate domes of diminishing closure so that only minor closures are found in northwestern Oklahoma.

Pre-Cherokee warping permitted truncation and overlap of the Dornick Hills, Springer, Caney, and pre-Pennsylvanian rocks around the flanks of the much restricted basin.

The late Pennsylvanian structural displacement was considerably masked by truncation of upthrown blocks and rapid deposition of Pontotoc conglomerate and arkosic sand in low areas. These grade laterally into normal marine shales, commonly called "Cisco" but containing Wolfcamp fusulinids.

Further rejuvenation of structures in late Wolfcamp time so restricted Permian seas that evaporitic deposition was inaugurated. These Wichita and Clear Fork rocks lap out over the granite arch.

Thus, the primary structure is a granite arch cut diagonally by en echelon features the summation of whose plunge created the bordering Anadarko and Ardmore basins even though grabens and horsts of tremendous displacement persist from one basin to the other across the Arbuckle-Wichita axis.

CONTINENTAL-MARINE MISSISSIPPIAN RELATIONS, NORTH-CENTRAL PENNSYLVANIA

BRADFORD WILLARD

The marine Mississippian of northwestern Pennsylvania meets and merges in north-central Pennsylvania with the continental Mississippian which spreads westward from the northeast. At their juncture, the two facies are confined between the overlying Olean or Pottsville, spherical-pebble conglomerate of the basal Pennsylvanian, and the underlying Devonian. The latter system terminates to the east in the Mount Pleasant red shale of the continental Catskill facies and to the west in the youngest marine Devonian, the Oswayo formation. The marine Mississippian consists of the Knapp formation and the Kushequa shale. The Knapp contains sandstone and discoidal-pebble conglomerate. Fossils from these beds are identified as of Kinderhookian age. The continental Mississippian carries the *Triphyllopteris* flora and consists of gray sandstone and pebble beds of the

* Published with permission of the President of the Eason Oil Co

Pocono group. These beds are identified as early Mississippian and considered equivalent to the lower part of the much thicker Pocono to the east. The Mauch Chunk red shale of the eastern Upper Mississippian has not been identified in north-central Pennsylvania; beds formerly so recognized are of Devonian age. In the region of the marine-continental transition, the Mississippian system is approximately 200 feet thick. As the marine facies passes eastward into continental, its fossils disappear, and the flat-pebble conglomerate, sandstones, and shale merge with the Pocono beds.

STRUCTURE OF THE ZINC-LEAD DEPOSITS OF NORTHWESTERN ILLINOIS

H. B. WILLMAN

The major zinc-lead deposits of northwestern Illinois are linear in outline, usually 100 to 200 feet wide and as much as 1 mile long, and have an orientation consistent with the regional joint system. The ore occurs principally along zig-zag and inclined fractures "pitches," along bedding-planes "flats," in breccia zones, and disseminated. Solution of relatively soluble limestone strata underlying the Ordovician Galena dolomite appears adequate to account for the ore-bearing structures in the Graham-Ginte ore body, the only ore body now well exposed.

In the Graham-Ginte ore body the combined thickness of the "oilrock" and "glassrock" limestones, which underlie the Galena dolomite, varies as much as 20 feet. The thickness variations of the "oilrock" have been interpreted previously as sedimentary or resulting from structural incompetence, but the abrupt thinning of the limestone beds, the persistence of argillaceous and siliceous beds, the configuration of the insoluble material to joints, and the interpenetration of large blocks of "oilrock" and "glassrock," simulating stylolites, favor thinning by solution. The limestone underlying the "glassrock" is not exposed, but it also may be thinned by solution.

The total vertical displacement of the beds is usually less than 10 feet and is not known to exceed 20 feet, which is no greater than the thinning resulting from solution.

Subsidence following solution explains the shallow structural trough in which the ore occurs, the fractures which converge upward above the trough, the bedding-plane openings, the brecciated "core-ground," and both the normal and reverse faults.

The local brecciation of the "pitch" and "flat" deposits before mineralization ended and the solution of limestone beds after mineralization suggests that solution, deformation, and mineralization were active contemporaneously.

APPLICATION OF PALEOECOLOGICAL METHOD TO AN EARLY TERTIARY COAL SEAM

L. R. WILSON

Samples of coal were collected from five exposures of a single coal seam near Wamsutter, Wyoming. This coal is of Green River age. The samples were macerated and studied microscopically for plant spores and pollen. Tertiary coals contain many genera of modern plants. The species are probably all extinct, but ecological inferences can be drawn from the present distributions of the genera. Almost 200 species of microfossils were observed in the Wamsutter coal. Counts of 1000 fossil spores and pollen from each collection were made. These give some idea of the composition of the Green River vegetation in the vicinity of the Red Desert of Wyoming. The various species of spores and pollen do not appear in the same abundance throughout the vertical extent of the seam. This fact suggests a change in the vegetative cover which might be related to topographic development or climatic variation during Green River time. In general the fossils depict a warm moist climate with phases of semiaridity. Several species of pollen suggest an adjacent topography of considerable relief. There is fair ecological correlation between the five exposures of coal. If the samples had been collected in short contiguous sections instead of at intervals through the seam, correlation of levels might have been more than approximate. With some modification the paleoecological method may be applied to Tertiary coals.

USE OF ELECTRICAL EARTH-RESISTIVITY SURVEYS IN ILLINOIS*

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For nearly 15 years the electrical earth-resistivity method has been used in Illinois to guide test drilling in the search for water-bearing sands and gravels in the glacial drift. Many areas in the State have been surveyed, and many municipal and industrial water supplies have been located and developed very economically as a result of this work.

Portable instruments are employed by the Illinois State Geological Survey in doing earth-resistivity work. The method utilizes a modified Gish-Rooney four-electrode system with commutated direct current applied to two steel current electrodes and a potential-drop measurement taken across two copper "potential" electrodes. Spacing of electrodes is by the Wenner system and is closely related to the diameter of the hemisphere of measurement. By increasing electrode spacing, measurements of resistivity to increasing depths are made.

Empirical interpretation methods suitable for the geological conditions obtaining in Illinois are applied, and all available surface and subsurface information is closely integrated with the resistivity data. Typically the method is used only for location of relatively thick sand or gravel deposits within 250 feet of the surface. Other applications such as the location of highway-construction materials have been made.

TERTIARY AND QUATERNARY GEOLOGY OF THE LOWER RIO PUERCO AREA, NEW MEXICO

HERBERT E. WRIGHT, JR.

The Lower Rio Puerco area is located partly in the Rio Grande depression (Basin and Range province) and partly in the Colorado Plateaus. During the late Tertiary the Santa Fe formation of at least 5000 feet of gravel, sand, and clay was deposited on alluvial fans and playas in the Rio Grande depression. The section of playa beds is at least 4000 feet thick. The stratigraphy of the Santa Fe formation reveals the paleogeography of the basins and highlands of west-central New Mexico for late Tertiary time.

The period of deposition was brought to a close by the rapid rising (maximum displacement 6500 feet) of the plateaus west of the basin along fault zones established during earlier Tertiary deformation. Thermal salt springs have been active on the fault zone since late Santa Fe time.

During the period of stability which followed, the extensive Ortiz erosion surface was developed across both the old plateaus and the basin deposits about 500 feet above the present Rio Grande. It is locally preserved by basaltic lava flows, caliche, travertine, or wind-blown sand. Subsequent alternating uplifts and periods of stability have produced surfaces 250–300, 175–200, 100–150, 50–75, and 25 feet respectively above the present Rio Grande, Rio Puerco, and Rio San Jose. The geomorphic map shows the distribution and type of cover on these several surfaces in the Lower Rio Puerco area. In addition a paleogeographic map was prepared with restored contours on the Ortiz surface over a more extended area in west-central New Mexico.

LUMINESCENT PHENOMENA AS AIDS IN THE LOCALIZATION OF MINERALS IN POLISHED SECTIONS

HERMAN YAGODA

On exposure to ultraviolet light a considerable number of minerals become readily discernible as a result of fluorescence or phosphorescence. The resultant optical activity is usually associated with the presence of minor constituents. The fluorescent pattern can on occasion be utilized for the estimation of the trace element causing the activity, a notable example being the estimation of the molybdenum content of scheelites. An annular cold quartz ultraviolet illuminator is described which permits the microscopic examination of fluorescing minerals in polished sections. Photomicro-

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graphs up to 150× magnification can be secured which are serviceable for aerometric analysis and for the study of mineral intergrowths.

The phosphorescence of minerals is best studied by direct contact printing avoiding the use of optical equipment. After irradiation the polished section is immediately placed on fast panchromatic film for about two minutes. On development a permanent record is secured showing the distribution of the phosphorescing constituents. This autoluminograph will often reveal constituents emitting radiations not visible to the eye but which activate the emulsion. By utilizing color-sensitive film a true color replica is recorded of the evanescent phosphorescence. Such patterns have proven useful in the study of the Franklin, N. J., mineral deposits. The autoluminographs localize the willemite (green), clinohedrite (orange), and hardystonite (purple); the accompanying calcite, franklinite, and zincite are nonluminescent and are depicted as voids in the autoluminographic pattern.

The thermoluminescence of hackmanite and certain varieties of fluorite can be recorded photographically by warming the thin section on a hot stage beneath the camera.

These luminescent properties are being employed in the study of the distribution of dust particles in lung tissue utilizing fluorescent hyalite opal and willemite as tracers for free and combined silica, respectively.

LATE TERTIARY FRESH-WATER MOLLUSKS OF SOUTHEASTERN IDAHO

TENG-CHIEN YEN

A deposit, hitherto assigned to the Salt Lake formation, at a locality in NW ¼ Sec. 8, T 12 S, R 43 E, about 9 miles northwest of Montpelier, Bear Lake County, southeastern Idaho, has yielded a species of pelecypod in Sphaeriidae and 20 species of gastropods that represent 2 genera of Valvatidae, 2 of Amnicolidae, 1 of Lymnaeidae, 1 of Physidae and 5 of Planorbidae. The elements seem to indicate a lacustrine deposit, formed possibly in Late Miocene time.

At least two species of "*Valvata*" from this deposit bear close resemblance in shell features to *Valvata eugeniae* Neumayr, *V. palmotici* Brusina, and *V. octonaria* Brusina, which were reported from nonmarine beds in the Balkan States and which are generally considered of Sarmatian and Pontian ages. So far as the present collection shows, the species of this deposit have little in common with those described from the Idaho formation, along the Snake River in Idaho, generally considered of Pliocene age.

MOLLUSCAN FAUNA OF MORRISON FORMATION (JURASSIC)

TENG-CHIEN YEN

Fresh-water mollusks have been reported from Jurassic deposits in North America since 1858. No less than 40 forms of pelecypods and gastropods have been described from limestone and shale beds, called in later years the Morrison formation and extensively distributed over the Rocky Mountain States.

The present study covers material partly collected at 14 localities in Colorado and Wyoming by the writer during June to August 1945 and partly from the collections of U. S. Geological Survey.

Molluscan material from Morrison beds exposed near Lyons, Loveland, and Ted Place, in north-central Colorado, are believed to be new records in distribution. Forms of *Planorbis* and a *Valvata*-like genus from a limestone bed southeast of Grand Junction in western Colorado indicate that the deposit is of fresh-water origin and belongs to the Morrison formation, though it has been taken by some to be of marine origin and part of the Sundance formation.

In addition to a systematic treatment of the molluscan fauna, bionomics of the formation as well as brief descriptions of the fossil localities therein contained are given.

P. 1215-1225 taken out for Index